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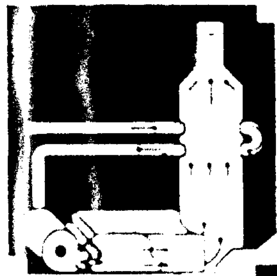
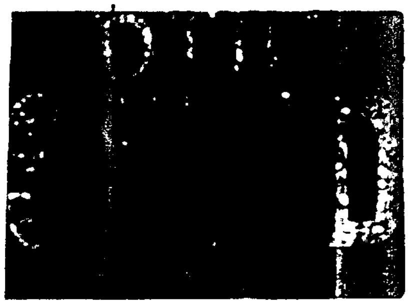
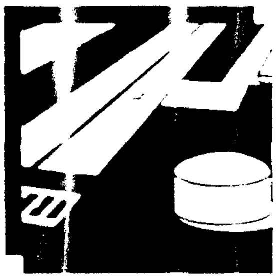
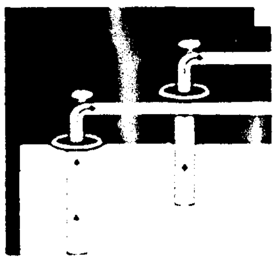
BASEWIDE ENGINEERING EVALUATION-COST ANALYSIS FOR SOIL VAPOR EXTRACTION

GENERAL EVALUATION DOCUMENT









McClellan Air Force Base

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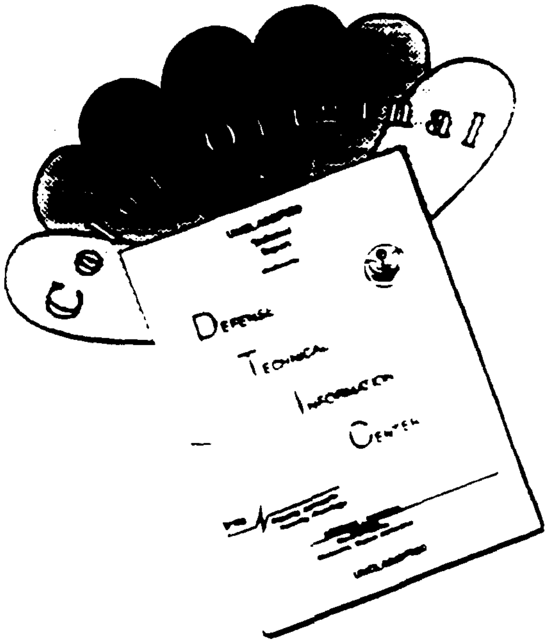

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McClellan Air Force Base

November 1993
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Section 1
INTRODUCTION

This Engineering Evaluation-Cost Analysis (EE/CA) document supports soil vapor extraction (SVE) as the preferred alternative for a basewide, non–time-critical removal action to remove volatile organic compound (VOC) contamination in soils at McClellan Air Force Base (McAFB). The National Contingency Plan (NCP) requires the lead agency to conduct an EE/CA or its equivalent for non–time-critical removal actions (40 CFR 300.415). The EE/CA process is a comparative analysis of removal action alternatives and is recorded in the EE/CA document for public review and comment.

A conventional EE/CA document generally supports a decision to take a removal action at a specified site or group of sites. McAFB and the regulatory agencies have modified the conventional EE/CA document to facilitate decision making and to streamline the administrative process in the McAFB Installation Restoration Program (IRP). This is accomplished by focusing on the *basewide applicability of a single technology* (SVE in this case), rather than on a single site. This General Evaluation Document establishes a site selection methodology that defines site conditions conducive to early action and to effective SVE application. Site Specific Documents will be written, as needed, to demonstrate that SVE should be applied in specific cases. At present, several contaminated areas have been identified for early application of SVE, and additional sites are expected to be identified in the future as site investigation and evaluation continues.

Presumptive Remedy and Plug-In Approaches

The efficient application of basewide SVE removal actions at McAFB relies on two parallel approaches:

*The **presumptive remedy approach** allows McAFB to rapidly select a technology that has repeatedly been proven effective under particular site conditions (in this case, SVE).*

*The **plug-in approach** allows McAFB to rapidly identify sites that are suitable for SVE removal action and to take quick action to remediate the sites.*

The term "presumptive remedy" refers to a technology that has been consistently selected as the preferred alternative through the alternatives analysis process. The U.S. Environmental Protection Agency (EPA) has embraced the development of presumptive remedies as one element of its ongoing effort to standardize and streamline the remedial and removal processes (USEPA, 1991e). EPA recently released three fact sheets. The first provides an overall guide to the presumptive remedies initiative and its effect

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on site cleanup, while the second and third fact sheets identify presumptive remedies for sites with soils contaminated by VOCs and municipal landfill sites, respectively (EPA, 1993a, 1993b, and 1993c). The presumptive remedy approach allows McAFB to select SVE as the preferred technology by demonstrating that SVE is effective under similar site conditions.

Section 3 of this General Evaluation Document contains a review of several remedy evaluation documents that support the choice of SVE for similar contamination situations at other National Priority List (NPL) sites. All of these documents follow the thorough evaluation procedure outlined in the NCP and collectively form the preponderance of evidence supporting the selection of SVE as a presumptive remedy for soils contaminated by VOCs.

The plug-in approach (figure 1-1) allows the McAFB and the regulatory agencies to evaluate sites rapidly to determine their suitability for the application of SVE as a removal action. This approach can be used when a Superfund site contains multiple areas or subsites that have similar physical characteristics and contain similar contaminants (USEPA, 1993d and 1993e).

The plug-in process consists of the following steps :

(1) The identification of a technology-specific response action

(2) The development of a selection methodology that outlines the process to evaluate both technical feasibility and the need for response action

(3) The use of the selection methodology to identify sites that can plug in the selected action

A site selection methodology has been developed for SVE removal actions at McAFB (section 4). The plug-in process for SVE removal actions requires the evaluation of both SVE feasibility and the need for removal action.

When making decisions about SVE removal actions, McAFB does not have to conduct a full-scale conventional EE/CA for each proposed site. If site conditions match those specified in the site selection methodology, the conventional process for alternatives evaluation and analysis is not necessary, and the site can plug in the SVE removal action. The decision process and administrative requirements for such sites will be streamlined by referencing this General Evaluation Document.

Sites that do not pass the site evaluation will not "plug in" the SVE removal action, but will be addressed by a separate response action or remedy.

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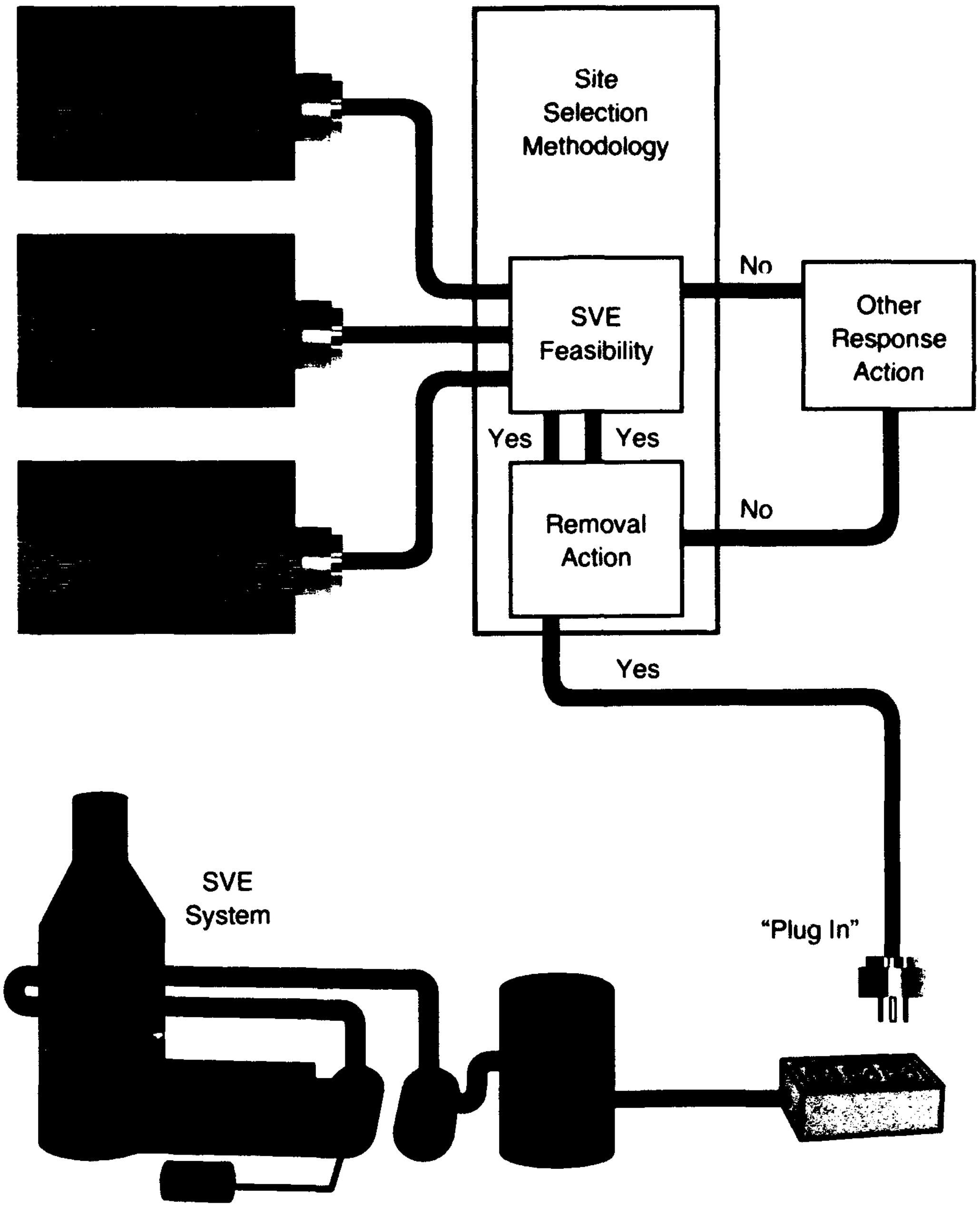

Figure 1-1
"Plug-In" Approach

Section 1

Framework for the Basewide SVE Removal Action: Superfund Accelerated Cleanup Model

The Superfund Accelerated Cleanup Model (SACM) is the new model developed by EPA to streamline the Superfund program and to be more responsive to the public's needs. Under this new paradigm, the distinctions between removal and remedial actions are eliminated. All sites will undergo one site assessment that combines appropriate elements from the current preliminary assessment/site investigation (PA/SI), remedial investigation/ feasibility study (RI/FS), and risk assessment. During the assessment process, early, short-term actions will be taken to reduce the majority of risk to human health and the environment. These short-term actions include cleanup activities generally taking no more than five years.

While the application of SACM to federal facilities has not yet been fully developed, McAFB has incorporated the main thrust of SACM and has focused the base IRP program on early actions to reduce risk. It is expected these early actions will be taken through the currently available response mechanisms, including both non–time-critical removal actions and interim remedial actions. To gain the most leverage from these actions, factors such as the magnitude and the imminence of the risk posed by sites will be considered in selecting sites for early action.

McAFB and the regulatory agencies have identified many sites that would be suitable for early action using SVE. The most prevalent pattern of contamination at these sites is high concentration of VOCs in soils extending from the surface to the groundwater table, which is approximately 100 feet below the ground surface. SVE has been demonstrated to be very effective in removing large amounts of VOCs from the soil, and there is no known incompatibility of SVE with other remedial technologies.

The application of SVE at McAFB will achieve the short-term goal of reducing risk to human health and the environment in the following ways:

Removing large quantities of VOCs from the soils

Intercepting the exposure pathways

Reducing additional VOC flux to the groundwater

Section 1

Integration of SVE Removal Actions with the McAFB IRP

Figure 1-2 illustrates the role of SVE removal actions in the McAFB IRP. During RI, field sampling is done both to identify sources and to define the nature and extent of contamination. At McAFB, shallow soil gas and downhole soil gas sampling are used extensively and successfully to characterize VOC contamination in soils. The rapid availability of soil gas measurements allows a quick appraisal of results so that further characterization needs can be determined and response decisions can be made (PTI, 1992; McAFB, 1993).

As soon as soil gas measurements and soil characteristics are available, a site can be evaluated for the need to take an SVE removal action before site characterization is complete. If the site is selected for an SVE removal action, the bulk of VOCs will be removed from the site while the remaining RI continues. Following the removal action, the site remedial decision will be evaluated with the additional RI results, taking into account other contamination (e.g., non-VOCs, metals in soils, or groundwater contamination) and any residual VOC contamination.

VOC Cleanup Levels

It is McAFB's strategy to reach agreement with regulatory agencies on final cleanup levels at the earliest possible opportunity rather than postponing the decisions until the final basewide Record of Decision (ROD) is written. Early determination of cleanup levels is important in deciding whether or not action needs to be taken. It also provides definitive system performance requirements early in the IRP process.

An important factor affecting VOC cleanup levels in soil is the state's antidegradation policy, which requires water and soil cleanup levels to be protective of the quality of waters in the state. The policy requires cleanup to background levels unless it is infeasible; if it is infeasible, then cleanup levels are the lowest levels achievable and need to be protective of groundwater beneficial uses. In other words, technical feasibility and cost-effectiveness have always been an integral part of determining cleanup levels under the antidegradation policy.

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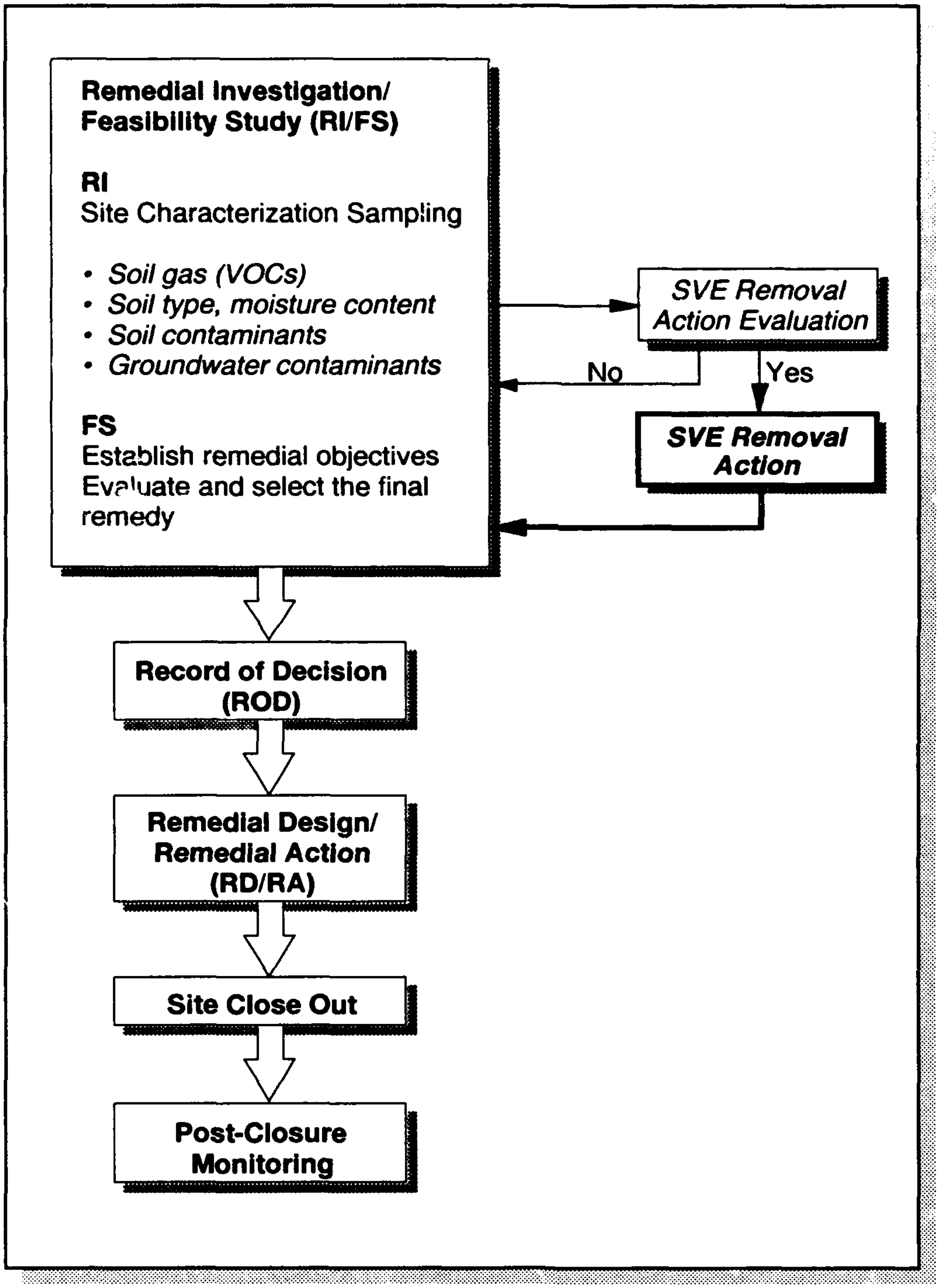

Figure 1-2
SVE Removal Action and IRP

Section 1

It is McAFB's strategy to use basewide SVE removal actions to facilitate the development of feasible VOC cleanup levels by generating site-specific cost and performance information. The antidegradation policy is interpreted as a goal for the basewide SVE removal action, with background levels used as the starting point. The SVE system will be designed and operated in an effort to achieve this goal. It is recognized that the removal action may not be able to attain this goal, but the data from the removal actions will be used to generate information regarding the feasibility of future SVE remedial actions. If background levels cannot be achieved, the cost and performance data will be used to determine appropriate cleanup levels that are both achievable and protective of groundwater beneficial uses. The evaluation process and decision will be documented in the basewide SVE ROD.

Decision Support Documents for Basewide SVE Removal Action

The basewide SVE removal action at McAFB is supported by a variant of the standard EE/CA. Traditionally, Superfund decisions are focused on a single site or on a group of sites, and each site is considered as a unique problem As a result, the traditional administrative process requires that a separate, comprehensive EE/CA be prepared for every proposed non–time-critical removal action. The standard EE/CA includes the following four sections on the analysis of removal action alternatives:

- Identification of removal action alternatives, based on screening a wide range of alternatives
- Description of the evaluation of each of the identified alternatives
- Summary of the comparative analysis, including the strengths and weaknesses of each alternative relative to the others
- Identification of the proposed removal action

The purpose of the detailed analysis of alternatives is to provide decision makers with adequate information to permit selection of an appropriate removal action.

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McAFB and the regulatory agencies believe that this conventional approach is not necessary in this situation (USEPA, 1993a and 1993b) and that the selection of the preferred removal action alternative can be simplified for the following reasons:

- Many sites at McAFB share similar characteristics. Because of these similarities, it is expected that response will involve similar approaches, making it possible to develop a selection process that is applicable basewide.

- There are few technical alternatives to SVE for VOC contamination in deep soils.

- There is a wealth of information demonstrating the effectiveness of SVE, and the decision makers are familiar with the performance of this technology.

Basewide SVE removal actions at McAFB will be supported by the Basewide EE/CA for SVE General Evaluation Document, as well as the Site Specific Documents. The General Evaluation Document focuses on generic aspects of representative sites at McAFB rather than on site-specific features. The General Evaluation Document outlines a long-term, comprehensive plan to standardize and streamline the use of SVE at McAFB. This is accomplished through the development of site selection methodology, SVE technology description, and cost estimating methodology, as shown in figure 1-3.

The General Evaluation Document is intended to be a living document, updated as needed to reflect new information from removal actions at McAFB and at other locations, as well as any other relevant information. Updates will be handled via addenda to the General Evaluation Document.

SVE removal actions for specific sites will be supported by focused, Site Specific Documents that will reference, but will not repeat, the General Evaluation Document. The Site Specific Documents will focus on site features that are either different from or absent in the General Evaluation Document. Each Site Specific Document will contain enough detail to support the Action Memorandum that authorizes an SVE removal action at a site.

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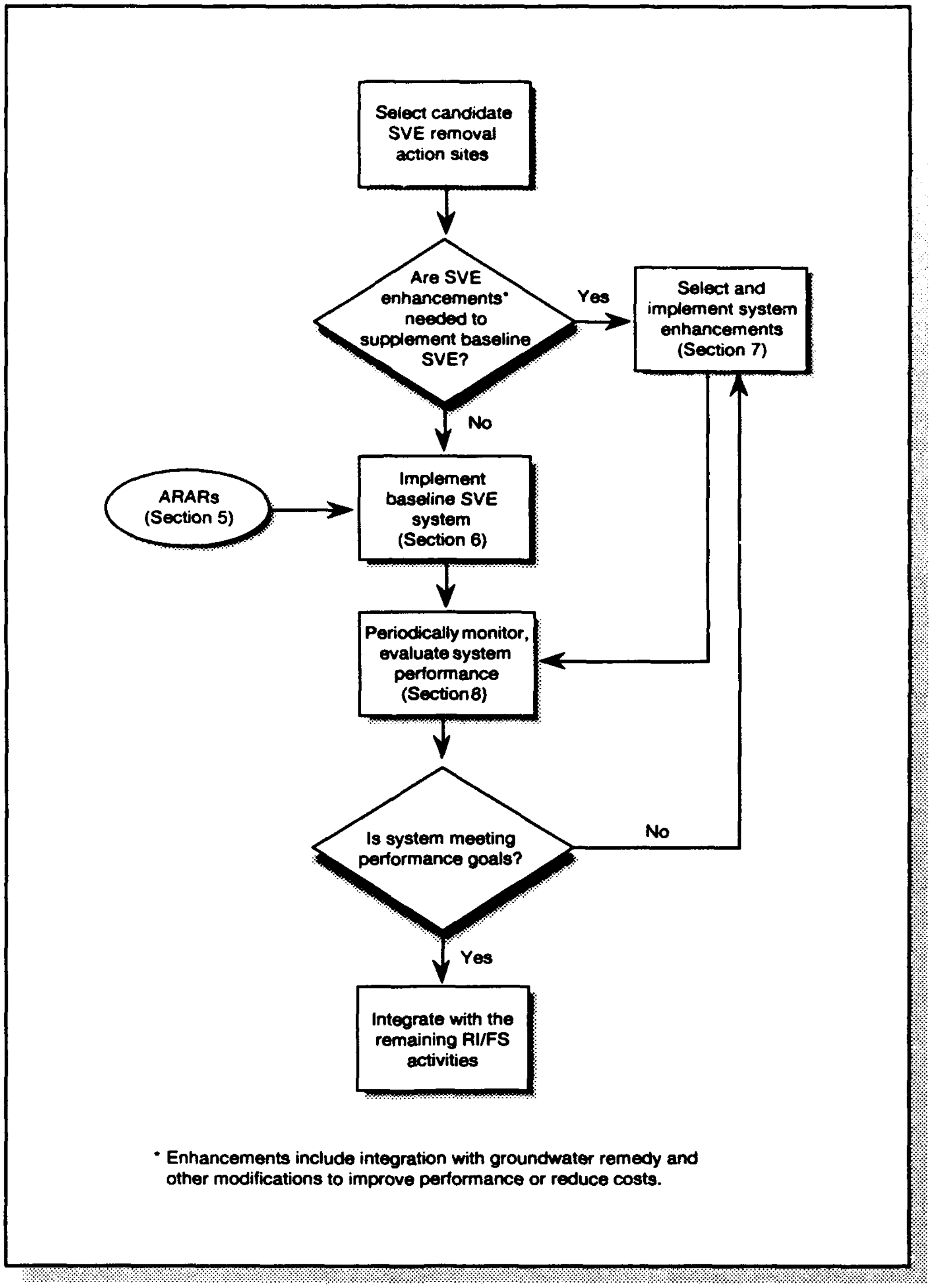

Figure 1-3
Decision Framework for SVE System Implementation

Section 1

Outline of the Site Specific Documents

1. Introduction

2. Site Characterization

   Investigation Results

   Interpretation

3. Justification of SVE Removal Action

4. Removal Action Objectives

   Scope

   ARARs

5. Conceptual Design and Cost

   Conceptual Design

   Cost Estimate

6. Implementation Plan for SVE Removal Action

Community Relations Plan

The community relations plan for the Basewide EE/CA for SVE consists of early community involvement in the planning process, as well as coordination during implementation. The following chronology highlights the key elements of t: community relations plan:

20 January 1993	Brief Technical Review Committee (TRC) on the plan for the basewide EE/CA for SVE: introduction, objectives, SACM, SVE as the presumptive remedy, and structure of the document
22 April 1993	Brief TRC on project update: EE/CA Interagency Agreement (IAG) schedule and removal vs. remedial process

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12 May 1993	Send draft EE/CA documents to community representatives for review and comment: General Evaluation Document, Site Specific Documents for Investigation Cluster (IC) 1, IC 7, and Operable Unit (OU) D/Site 3
15 July 1993	Send additional draft EE/CA documents to community representatives for review and comment: Site Specific Documents for OU C1 and Site S
22 July 1993	Review EE/CA with TRC: SVE EE/CA process elements, early action results incorporated into the ROD process, plug-in concept as applied to SVE removal actions, and six candidate sites
1 September 1993	Make EE/CA documents available for a 30-day period of public review and comment: General Evaluation Document, Site Specific Documents for IC 1, IC 7, OU C1, OU D/Site 3, and OU D/Site S
22 September 1993	Hold a public meeting
15 November 1993	Make final EE/CA, action memorandum, and responsiveness summary available to public

The community relations plan for future SVE removal actions is similar and will consist of the following events:

TRC presentations to involve public participation in planning, decision making, and implementation

Release of fact sheets to describe the progress and to announce upcoming events

Release of Site Specific Documents for public review and comment

Public meetings on Site Specific Documents

Section 2
BACKGROUND

McClellan Air Force Base is located approximately seven miles northeast of downtown Sacramento, California. The main base facility includes 2,949 contiguous acres which are bounded by the city of Sacramento to the west and southwest, the unincorporated areas of Rio Linda to the northwest, and North Highlands to the east.

Land use in the vicinity of McAFB consists of a complex combination of military, industrial, commercial, residential, and agricultural uses, as shown in figure 2-1. The majority of the land use surrounding the base is residential. In the Rio Linda area northwest of the base, most of the land is in agricultural-residential (large-lot) use. To the southwest and east of the base are low-density residential zones supporting population density of 5–30 persons per acre. In the same area, there are also parcels designated for commercial and office use. The total population of the surrounding communities in 1980 was 107,000.

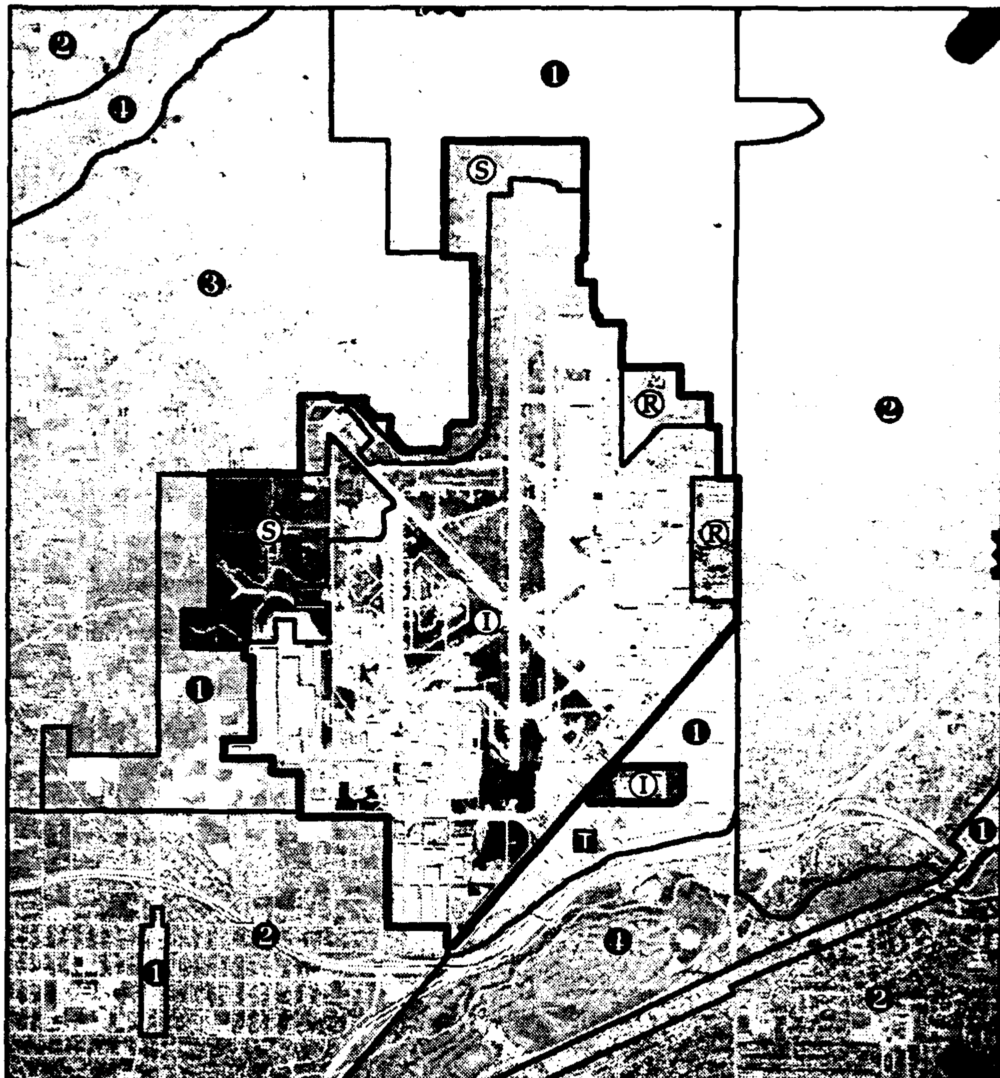
The climate in the McAFB area is characterized by hot, dry summers and cool, moist winters. The average temperatures vary from the mid-40s (°F) in winter, to the mid-70s (°F) in the summer. Approximately 17 inches of the 19.8 inches average annual precipitation falls between November and April. The mean annual evapotranspiration rate is about 45 inches per year.

The base is located in the Great Valley Physiographic Province, consisting of the Sacramento Valley to the north and the San Joaquin Valley to the south. The base is located on the west side of the Victor Plain, an alluvial plain located along the eastern side of the Sacramento Valley. The plain was created by the deposition of sediments eroded from the Sierra Nevadas over geologic time. The land surface slopes gently from about 75 feet above mean sea level on the east side of the base to about 50 feet above sea level on the west side.

Surface water in the vicinity of McAFB drains southwesterly. Drainage on and around McAFB include Magpie, Second, Robla, and Don Julio Creeks. The primary recipient of on-base drainage is Magpie Creek, which enters McAFB from the east, merges with several tributaries, and exits to the west.

History

McClellan Air Force Base was established by Congress in 1936 as an aircraft repair depot and supply base. Initially named the Sacramento Air Depot, the facility was dedicated in 1939. In the early 1950s, the primary mission of McAFB changed from that of a bomber depot to that of a jet fighter maintenance depot. Currently operating as an installation of the Air Force Materiel Command, McAFB employs approximately 16,800 military and civilian



Off Base
- ❶ Commercial/Industrial
- ❷ Residential (high density)
- ❸ Residential/Agricultural (low density)
- ❹ Open Space (recreational)
- 🅃 Solid Waste Disposal Facility (transfer station)

On Base
- Ⓘ 81.2% Industrial
- Ⓢ 15.1% Sensitive Area
- Ⓡ 3.7% Residential

Figure 2-1 *Current Land Use at McAFB and Surrounding Areas*

Section 2

personnel with the primary mission of management, maintenance, and repair of aircraft, electronics, and communication equipment. These activities, and the associated housekeeping and support services, are carried out by units of the Air Force Materiel Command. Additional tenants of the base include both military and civilian entities.

In fulfilling its past and current mission to defend the United States through the operation and maintenance of aircraft, McAFB was and is engaged in a wide variety of operations involving the use, storage, and disposal of hazardous materials. These include industrial solvents, caustic cleaners, electroplating chemicals, heavy metals, polychlorinated biphenyls (PCBs), low-level radioactive wastes, and a variety of fuel oils and lubricants.

In the late 1970s, groundwater contamination was discovered at McAFB; subsequent studies identified past waste disposal practices as the likely source of this contamination. In 1979, McAFB developed a comprehensive program to maintain drinking water quality and to remediate contamination both on- and off-base. In 1981, the McAFB effort was incorporated into the new Air Force IRP. On 22 July 1987, McAFB was placed on EPA's NPL.

To date, approximately 250 waste sites, potential release locations (PRLs), and other areas that warrant investigation have been identified. These have been grouped into 11 OUs, each of which corresponds to an area on the base where specific industrial operations and/or waste management activities have taken place. The eleventh operable unit—OU GW—is basewide and addresses groundwater remediation.

Groundwater Contamination

Groundwater beneath McAFB occurs in both confined and unconfined conditions, and has been tapped for municipal, domestic, and agricultural purposes for many years. Currently, the groundwater level is about 100 feet below ground surface, compared with a depth in 1960 of 30–40 feet. Withdrawals by the base and surrounding communities have altered the contours of the groundwater surface, producing a local minimum just south of the base. The result is that groundwater flows under the base from northeast to southwest.

Groundwater samples collected on and in the vicinity of McAFB have shown the presence of a variety of contaminants, principally VOCs and metals. Groundwater continues to be used by some residences for irrigation purposes; however, the provision of public water as part of the Air Force response to the contamination problem has reduced the reliance on individual domestic wells in areas to the west and southwest of the base.

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The following eight contaminants have been consistently detected in groundwater at levels above federal drinking water standards:

- Benzene
- Carbon tetrachloride
- Trichloroethene (TCE)
- Vinyl chloride
- 1,1-dichloroethene (DCE)
- 1,2-dichloroethene (DCE)
- 1,2-dichloroethane (DCA)
- Tetrachloroethene (PCE)

Seven other contaminants are consistently detected at levels below federal drinking water standards: acetone, bromodichloromethane, 2-butanone, 1,1-DCA, 4-methyl-2 pentanone, toluene, and trichlorofluoromethane.

The contaminant having the greatest spatial extent is TCE. Approximately 400 acres are underlain by groundwater plumes having TCE concentrations above the federal drinking water standard of 5 μg/l, or parts per billion (ppb).

Using concentrations of TCE above 1 ppb, groundwater contaminant plumes underlay about 520 acres, or about 18 percent of the total area of the base. The TCE plume also extends to cover an additional 70 acres off base. Figure 2-2 shows the groundwater contamination area on and around McAFB.

Soil Resources and Contamination

Soils in the vicinity of the base are variable. The surface soils result from the weathering of mixed alluvium derived from a variety of sources, mainly granitic rock. The stratigraphy beneath the base is complex, as is typical of heterogeneous fluvial deposits. Individual lithologic units undergo abrupt lateral and vertical facies changes or pinch out over a short distance. The mechanism for deposition of these units is a large, sinuous stream system that migrated across the area, depositing sandy materials within a meander belt, and finer silts and muds across a broader flood plain. Typical sediments present are sands, silts, clays, and, rarely, gravels. The most prevalent soils at McAFB are amenable to SVE.

Figure 2-3 shows the environmental condition of soils at McAFB based on soil gas sampling. The shaded dots indicate various concentrations of volatile analytes which were detected in soil gas at that particular location, without regard to depth. The highest concentrations of individual volatile compounds found in the boreholes used for characterization were in OU B. Data from extraction wells at Site S in OU D also show high VOC concentrations. The Site S extraction field is very small (0.22 acres) and is represented by a single

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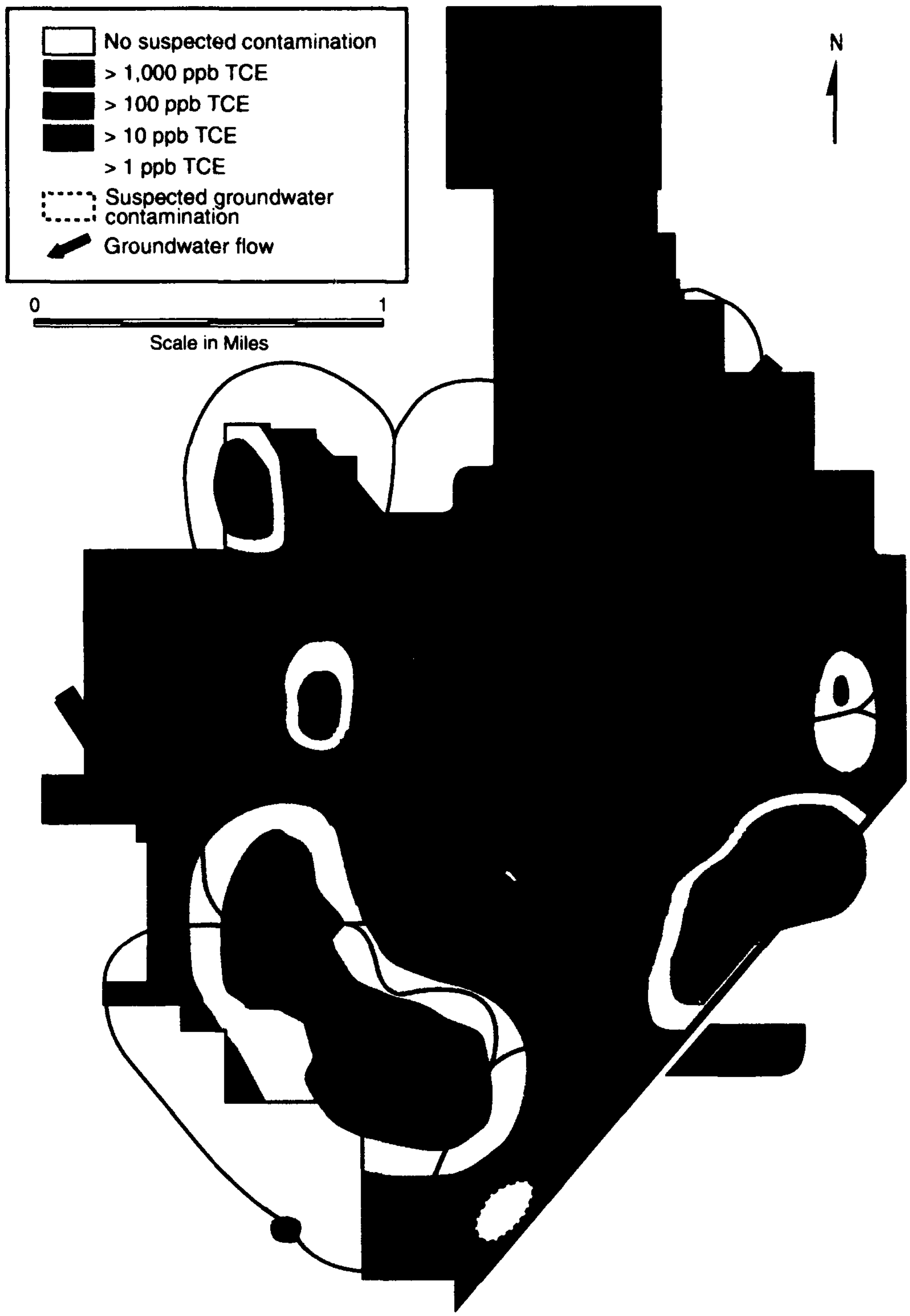

Figure 2-2
Groundwater Contamination at McAFB

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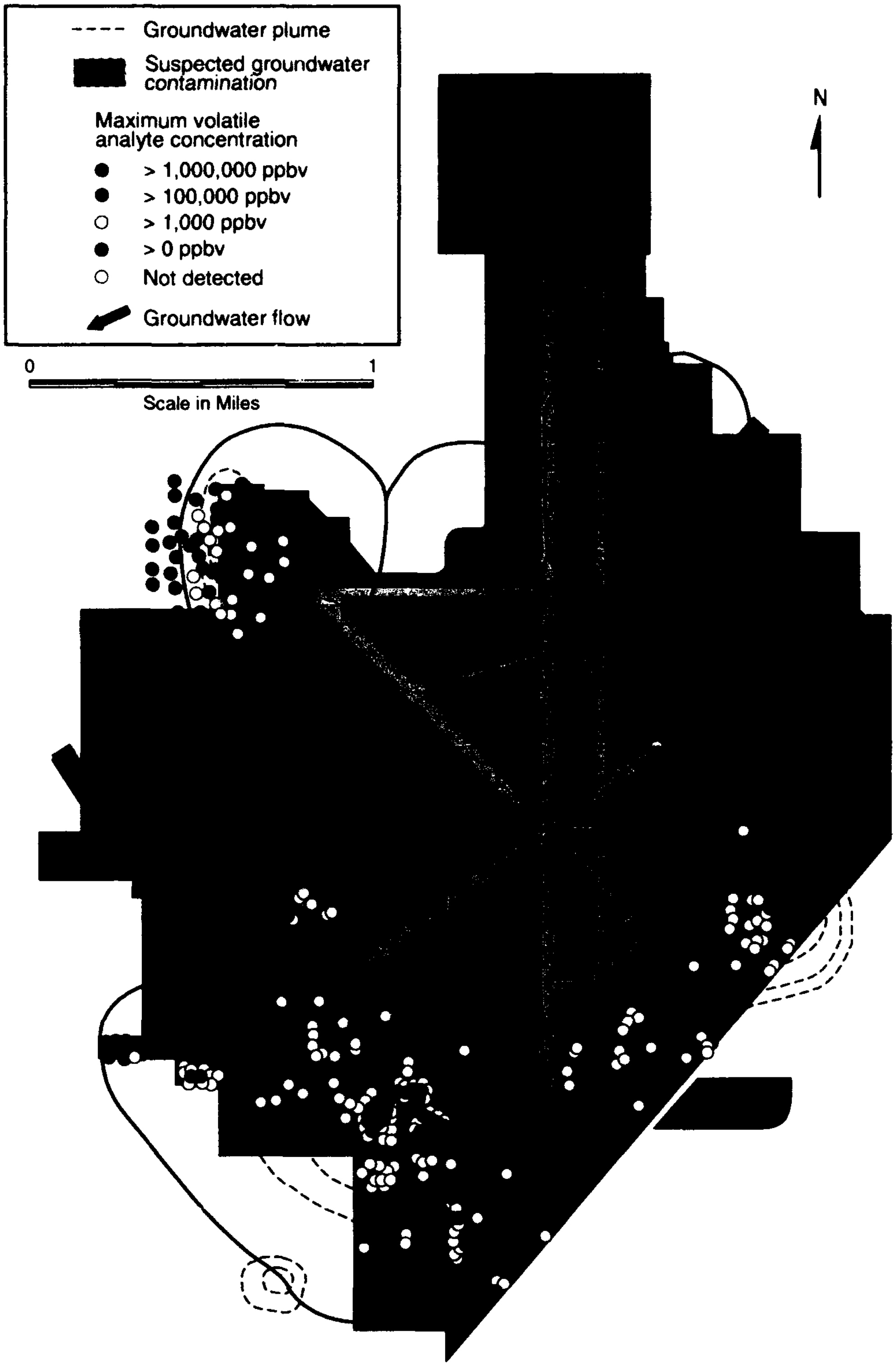

Figure 2-3
Soil Contamination at McAFB (Soil Gas Analyses)

Section 2

point in figure 2-3. The areal extent of known soil contamination, based upon soil gas measurements indicating detectable levels of volatile compounds, is approximately 150 acres, or about 5 percent of McAFB.

Volatile organic compounds constitute the most widespread and the most common subsurface contamination at McAFB. Compounds with significant concentrations in decreasing order of frequency of detection in soil gas are TCE, PCE, 1,1-DCE, 1,1,1-trichloroethane (TCA), and freon-113. In addition, the following compounds are commonly identified in soil gas, but at lower concentrations: cis 1,2-DCE, 1,1-DCA, trichlorofluoromethane, dichlorodifluoromethane, trans 1,2-DCE, 1,2-DCA, vinyl chloride, carbon tetrachloride, chloroform, methyl benzene, xylenes, and benzene. Of the compounds most frequently reported, TCE and PCE contribute the bulk of the contaminant mass in some areas, but 1,1,1-TCA and 1,1-DCE are as significant in other areas. Most of these compounds have also been detected in groundwater at various locations underneath the base. All cited compounds are amenable to recovery by SVE from soils.

Section 3
SVE AS THE PRESUMPTIVE REMEDY AT MCCLELLAN AFB

Soil vapor extraction is a remedial process wherein a vacuum is applied to the unsaturated (vadose) soil zone to induce the volatilization and subsequent removal of hazardous contaminants in the soil. The process is known in the industry by other names, including vacuum extraction, soil venting, in-situ volatilization, and enhanced volatilization. There has been nearly a decade of experience with the SVE process, and it is now an accepted, cost-effective technique for removing VOCs from soil. In a recently released fact sheet, EPA identified SVE as the primary presumptive remedy for CERCLA sites with soils contaminated by VOCs (USEPA, 1993b).

Based upon the review of RODs at 11 California NPL sites, the presumptive remedy for vadose zone soil contamination by VOCs has been determined to be SVE. This technology will satisfy the removal objectives for the majority of McAFB sites with VOC contamination and will permit an early reduction of the mobility and quantity of VOCs in soils. SVE, together with process enhancements and off-gas treatment (as required), can remove and treat volatile contaminants from vadose zone soils at most McAFB sites. Whether or not SVE is an appropriate technology for specific McAFB sites will need to be decided based upon a site-specific evaluation of SVE criteria, as described in section 4 of this document.

Selection of a Presumptive Remedy

The standard procedure for selecting the preferred alternative for non–time-critical removal actions is a three-step process that includes the following elements:

- Identification of removal action alternatives, wherein a large set of alternatives is screened
- Detailed evaluation of the identified alternatives based upon effectiveness, implementability, and cost considerations
- Comparative analysis of the identified alternatives

This extensive evaluation is designed to provide decision makers with sufficient information to justify the choice of the preferred alternative. However, EPA has recognized that at times site conditions are so well suited to a particular technology that the technology can be presumed to be appropriate without an exhaustive evaluation. This so-called presumptive remedy approach allows the selection of a technology or process option which has been repeatedly shown to work within the range of conditions present at the site. In the specific instance where SVE is to be employed for removing VOCs from soils, there is no need for a protracted evaluation procedure because decision makers are familiar with this technology.

Section 3

This section justifies the selection of SVE as a presumptive remedy for VOCs in vadose zone soils by demonstrating that SVE has been repeatedly proven to be effective under similar site conditions. Included is a review of 11 California RODs that have selected SVE as the preferred remedy. All of these RODs follow the evaluation procedure outlined in the NCP [40 CFR 300.430 (e)(9)(iii)], and form the preponderance of evidence supporting SVE as a presumptive remedy.

During the past five years, SVE has been selected as a final remedy at 11 Superfund sites in California. The sites which have been identified, and the dates of the associated Records of Decision (RODs), are shown below.

Superfund site RODs reviewed:

National Semiconductor, Santa Clara (September 1991)

Signetics, Sunnyvale (September 1991)

Van Waters & Rogers, San Jose (September 1991)

Teledyne Semiconductor, Mountain View (March 1991)

Intersil, Cupertino (September, 1990)

Watkins-Johnson, Scotts Valley (June 1990)

Fairchild Semiconductor, Mountain View (May 1989)

Intel, Mountain View (May 1989)

Raytheon, Mountain View (May 1989)

Fairchild Semiconductor, San Jose (February 1989)

IBM, San Jose (December 1988)

Three of these sites (Fairchild Semiconductor, Intel, and Raytheon) are very close in proximity, and were considered collectively within a single FS. Three of the sites (Signetics, Teledyne Semiconductor, and Intersil) have multiple subsites.

Section 3

ROD Review: Similarity with McAFB Sites

The ROD sites reviewed have attributes comparable to those at McAFB, and a comparison of soil characteristics, depth of soil contamination, and soil contaminants suggests that SVE could be successfully employed at the McAFB sites. This comparison is shown schematically in figure 3-1. For example, most of the ROD sites are underlain by complex soils, ranging in particle size from sand to clay, and are often the result of alluvial processes. The soils at McAFB are also varied, primarily interbedded sands, silty sands, and silts. Note that all the ROD sites were underlain by clayey soils to some extent. Thus the presence of clay is not in itself an indication that SVE could not be implemented at a site.

The depth of soil contamination in the vadose zone at the ROD sites often favored SVE as the final remedy. Although contamination at most of the sites is less than 50 feet in depth, it sometimes extends as deep as 120 feet. The cost of removing the volume of contaminated soil associated with these depths would be prohibitive. This situation parallels that at McAFB, where groundwater is nearly 100 feet below the surface.

The contaminants of concern at the ROD sites are primarily VOCs, which are amenable to treatment by SVE. The principal contaminants included PCE, TCA, TCE, freon-113, and vinyl chloride. These same compounds are among the principal contaminants at McAFB. Therefore SVE can be expected to be successful in the removal of these compounds if other factors are favorable.

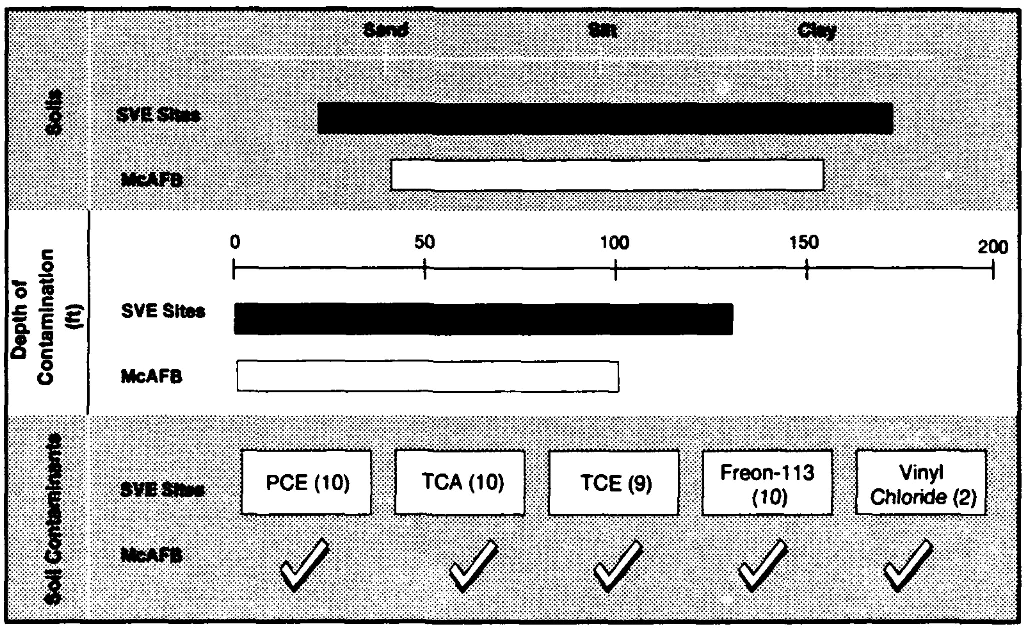

Figure 3-1
A Comparison of California SVE ROD Sites to McAFB Sites

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ROD Review: Basis for Rejecting Non-SVE Alternatives

There are four general response actions—apart from a no-action alternative—that can be applied to VOC-contaminated soils: institutional controls, containment, removal, and treatment. Each general response action can be achieved through one or more technologies, and each technology may have one or more process options. Not all options will be technically implementable at a given site. Only those options which passed an initial screening procedure are evaluated as remedial alternatives in the RODs. Because these sites have been shown to be similar to those encountered at McAFB, it is reasonable to reject those options which did not survive the initial screening, i.e., were not evaluated as remedial action alternatives in the RODs. By focusing on the alternatives considered in the 11 RODs, the selection of technologies that would most likely be successful at McAFB sites can be facilitated. The general response actions noted above will therefore be considered in light of the 11 ROD sites, as well as specific conditions at McAFB.

Only a few technological processes survived the initial screening at the ROD sites, and were thus further evaluated as potential action alternatives: deed restrictions, capping, removal followed by disposal, SVE, soil flushing, and soil aeration. Except for SVE, these processes were generally rejected as long-term, stand-alone remedies at the various ROD sites for reasons indicated in table 3-1, and discussed below. The remedies which were selected at the ROD sites are summarized in table 3-2.

Alternative	Basis for Rejection	Applicability to McAFB
Capping	• No reduction in soil contamination	Same objection applies
Institutional controls	• Lack of permanence, long-term effectiveness	Same objection applies
Excavation with disposal or soil aeration	• Short-term adverse health effects	Same objection applies
	• Difficult to implement (access, impact on other operations)	Same objection applies
	• Residual contamination in unexcavated soils	Same objection applies
	• Air emissions	Same objection applies
	• High cost	Same objection applies
Soil flushing	• Limited effectiveness	Same objection applies
	• Incompatibility with slurry walls	Not applicable
	• High cost	Same objection applies

Table 3-1
Rejected Long-Term, Stand-Alone Remedial Alternatives for ROD Sites

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Table 3-2 Interim, Final, and Rejected Soil Remedies for Selected California SVE ROD Sites

Site Name	Institutional Deed Restrictions	Containment Capping	Removal	Treatment SVE	Treatment SF	Treatment SA	Remarks
National Semiconductor	S		I/S	P		S	Soil aeration to be used for shallow areas where SVE is not effective (e.g., areas contaminated with semi-VOCs; earlier soil removals involved semi-VOC contamination). SVE was included in all alternatives; no other stand-alone alternatives were considered.
Signetics (Signetics)			I	I/P			Expanded SVE for final action. SVE was included in all alternatives; no other stand-alone alternatives were considered.
Van Waters & Rogers	S	R, S		P		R	Only hot spots (>10 ppm PCE, or TCE, or TCA) will be remediated to 1 ppm total VOCs; no remediation of other areas. Emissions pose a problem with soil aeration.
Teledyne Semiconductor (Spectra-Physics)	R		I/R	I/P			Current SVE system will be expanded. No permanence for deed restrictions; high short-term health risks for excavation because most areas are currently paved.
Intersil (Intersil)			R	I/P		R	Rejected alternatives had higher costs, short-term adverse health effects, and caused disruptions at the facility.
Intersil (Siemens)			S	I/P			Only 40 cubic yards to be removed. SVE was included in all alternatives; no other stand-alone alternatives were considered.
Watkins-Johnson		S		P			SVE included in all alternatives; no other stand-alone alternative considered; no contamination in top 15 feet of soil.
Fairchild Semiconductor (Mountain View)				P	R	R/S	Soil flushing might interfere with the slurry wall remedy.
Intel				P	R	I/R/S	Soil flushing might interfere with the slurry wall remedy.
Raytheon				P	R	R/S	Soil flushing might interfere with the slurry wall remedy.
Fairchild Semiconductor (San Jose)			I	P			Pilot study indicated SVE was effective in soils with >1 ppm TCA. SVE included in all alternatives; no other stand-alone alternatives considered.
IBM			I	P			Excavated 23,000 cubic yards of soil. SVE included in all alternatives; no other stand-alone alternatives considered.

Treatment: SVE = soil vapor extraction; SF = soil flushing; SA = soil aeration

Remedy: P = primary remedy; S = supplementary or contingent remedy; I = interim action already completed; R = rejected as a stand-alone remedy

References: US EPA 1988, 1989a, 1989b, 1989c, 1989d, 1990a, 1990b, 1991a, 1991b, 1991c, 1991d

Institutional controls limit access to contaminated areas, thereby eliminating exposure to hazardous substances. Limited access is commonly accomplished by one of two means: physical restrictions (e.g., security fences) or deed restrictions. Such actions do not reduce the mobility, toxicity, or volume of contamination in the soils, and do not constitute a permanent remedy. This

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alternative was not selected as a final remedy at any site, although several used it as a temporary measure in conjunction with another remedy, such as SVE.

Containment technologies are used to restrict the migration of soil VOCs to groundwater. Capping involves the placement of an impermeable layer (e.g., asphalt, concrete, synthetic membranes) over the site to prevent percolation through the contaminated zone and carrying VOCs to the groundwater. Only a single ROD site even considered capping as a stand-alone remedy, although two of the sites chose to use it in conjunction with other selected remedies. As a supplemental remedy, capping of a site has the advantage of preventing or reducing the infiltration of water and subsequent leaching of contaminants from the vadose zone into groundwater. It also reduces fugitive dust emissions, as well as emissions of volatile contaminants from the soil to the air.

Removal involves the excavation of contaminated material using ordinary construction equipment. The contaminated material can then be disposed of off-site or subjected to further treatment. Excavation was considered at the majority of the ROD sites, and was selected as a part of the final remedy at nine of them. Because excavation is expensive, it was generally considered only where relatively small volumes of contaminated soil were involved. Also, most of the physical removals at these sites were conducted in the past as interim actions. Only two of the sites selected removal as a remedial alternative. Because contamination at McAFB sites extends as much as 100 feet below the surface, excavation would be prohibitively expensive as a stand-alone remedy.

Potential treatment technologies can be classified as in-situ, meaning treating the soil in place, or ex-situ, which requires removal before treatment. Both SVE and soil flushing are in-situ processes that were considered in the RODs reviewed. SVE was considered and selected as a remedial action alternative at all the sites reviewed, which was a primary criterion for their original selection for review. In addition, three of the ROD sites evaluated soil flushing, a technique whereby soil contaminants are transported to the groundwater and subsequently treated, as a remedial alternative. Soil flushing was not selected as a final remedy at any of these sites because of its potential to interfere with another remedy. A pilot study of soil flushing at a fourth site was successful, but was not considered as an alternative remedy because the area available for infiltration ponds did not coincide with the areas requiring treatment. Only one additional technology, soil aeration, was evaluated in the RODs. Soil aeration, wherein contaminated soil is excavated and spread on the ground to facilitate aeration, was considered at six of the ROD sites, and selected as part of the final remedy at four sites. As stated above, extensive excavation would

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be prohibitively expensive at McAFB sites, so that in-situ technologies provide the only practical alternatives. Moreover, emissions from soil aeration would be difficult to capture and treat.

ROD Review: Basis for Selecting SVE

Each of the 11 RODs reviewed included a detailed analysis of remedial alternatives for contaminated soil in the vadose zone and subjected SVE to comparisons with other technologies. The selection of a final remedial action alternative was accomplished for each ROD within the framework of the nine criteria specified in the NCP. Figure 3-2 summarizes the reasons that SVE was selected as a final remedy at these sites. The fact that the RODs for these sites specified SVE as the primary remedial alternative supports the use of SVE as a presumptive remedy at McAFB. Most of the RODs reviewed specified activated carbon would be used to meet air emissions requirements in conjunction with SVE treatment. No other off-gas treatment alternative was specified by any ROD.

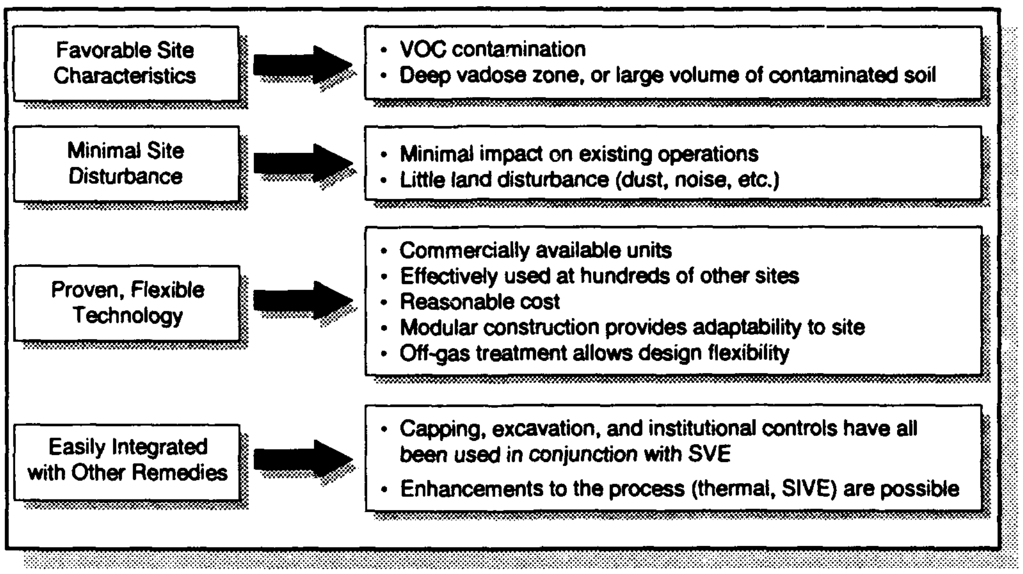

Figure 3-2 *Advantages of SVE Leading to Its Selection as the Primary Remedy at 11 California Sites*

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SVE Performance Information

Site S Treatability Study

The application of SVE at McAFB has been demonstrated in the SVE Treatability Investigation under way at Site S in OU D. The Site S SVE system has been installed and was brought into successful operation in March 1993. Site S covers an area of approximately 9,000 square feet (0.23 acres) in OU D. It is 1 of 12 waste disposal sites in OU D, and was identified as a former fuel and solvent disposal pit. The waste in Site S is overlain with approximately 10 feet of soil, and extends to a depth of about 28 feet below ground surface. Borings have detected soil concentrations of a variety of VOCs (including chlorinated hydrocarbons and petroleum hydrocarbons) ranging from 1,000-30,000 µg/kg, while showing low levels of organic carbon and metals.

During its initial period of operation, the SVE system demonstrated high removal rates for chlorinated hydrocarbons and for the degradation products of hydrocarbons, thus verifying process effectiveness of the site. Over a period of eight weeks, the SVE system withdrew and the fluidized bed catalytic oxidizer destroyed approximately 46,000 pounds of VOCs. The oxidizer achieved a destruction or removal efficiency of more than 99 percent, and monitoring showed that VOC emissions were below prescribed limits. The SVE system also created aerobic conditions underground, which supported biodegradation of the petroleum contamination. Oxygen and carbon dioxide measurements showed that approximately 150,000 pounds of hydrocarbons were degraded during the initial operation.

Although the SVE system at Site S performed extremely well in removing contamination from soils, it was shut down after approximately six weeks of operation because of several nuisance problems arising from its operation. These included acid gas emissions and a noise complaint.

The oxidation of the chlorinated hydrocarbons leads to the formation of hydrochloric acid (HCl), which is emitted as a gas. Acid gas emission had been expected, and monitoring showed that the amounts emitted were about two thirds of the predicted quantity and were within regulatory limits. However, the ground level concentrations were somewhat higher than expected, and led to complaints from on-base personnel. The system was shut down so that an acid gas scrubber system could be designed and installed, with restart scheduled for early 1994.

It has always been the base's intent to pursue alternative technology for off-gas treatment to minimize or eliminate NOx production. Therefore, while waiting for the installation of the scrubber, McAFB is currently evaluating a resin adsorption system at Site S. In addition to minimizing NOx production, the

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adsorption system will also minimize HCl emission. In contrast to the catalytic oxidation system that oxidizes the chlorinated hydrocarbons, a resin system adsorbs the contaminants as they are pumped from the ground. The resulting gas stream is then sent to the catalytic oxidation system for destruction of remaining contaminant gases. The resin is periodically heated to desorb the contaminants, which are then condensed and collected for off-site disposal. The resin is then ready for another adsorption cycle. Two resin beds are provided to allow for continuous system operation. Because most of the chlorinated hydrocarbons are removed before the catalytic oxidation stage, the amount of HCl generated should be extremely small.

The second problem was noise from the electric motors and vacuum pumps. The original SVE system had two noise control measures including a muffler and an enclosure for the vacuum system. In spite of the control measures already in place, the noise led to a complaint from an off-base citizen. As a result, a sound wall was installed as an additional control measure to reduce noise levels by shielding line-of-sight noise transmission.

Another issue of concern relates to the emission of dioxins from the SVE gas treatment unit. Dioxins can sometimes be found in the blowdown from dewatering the SVE gas, or can be formed from the oxidation of chlorine-containing compounds in the gas treatment system. Sampling of the blowdown and the exhaust gas have shown dioxin levels well below levels of concern. However, it should be noted that the potential for dioxin emissions does exist, and design and operational safeguards must be implemented to control such emissions. These will include operating the fluidized bed in the catalytic oxidation unit at sufficiently high temperatures and gas flow rates to enssure proper mixing of the catalytic media and high destruction efficiency of the contaminants.

Modifications and enhancements of the baseline SVE system are planned for testing at McAFB. These may allow reductions in cost, improvements in removal efficiency, or emission reductions. Some changes may also assist in tailoring the SVE system to a particular site. Many of these changes will be tested on the Site S system. The provision at Site S for sampling of the gas stream at multiple points in the process, and even removal of a portion of the gas stream for "slip stream" testing, makes such changes relatively easy to make and evaluate. In addition to the testing of resin adsorption system mentioned above, the slip stream from Site S has been used for bench-scale testing of an electron beam technology.

Other Sites

All of the eleven NPL sites addressed in the ROD review have progressed into the subsequent remedial design and remedial action (RD/RA) phase to

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implement the SVE system. They are at varying stages of implementation ranging from design, pilot testing, and ongoing operation to completion. At Intersil—Cupertino, the SVE system has been demonstrated to have attained soil cleanup standards of 1 mg/kg total VOCs and 10 mg/kg total semi-VOCs; the curtailment of the SVE system has been approved (Geomatrix, 1993). At IBM—San Jose, SVE systems have been applied in five areas, and they have effectively removed nearly 50,000 lbs of organic compounds. In one area of the IBM site, SVE achieved shutoff criteria, and confirmatory soil samples found no organic compounds (Kennedy/Jenks, 1993).

A recent review (Crotwell, et al., 1992) strongly supports the use of SVE for removal of the major portion of VOC contamination in subsurface soil. VOC concentrations at the 13 sites reviewed were reduced by 64 percent to 99 percent; VOC concentrations were reduced by more than 90 percent at 9 of the sites. At some sites, the ineffectiveness of the treatment was attributed to specific site conditions, such as the presence of geological tar deposits. The review further indicated the widespread use of SVE, noting it comprised over 18 percent of the selected remedies at Superfund sites. The authors caution that some portion of contamination trapped inside the soil matrix could not be removed by SVE, so the process could not be relied upon to return contaminated sites to their original pristine condition. However, as discussed in section 1, cleanup levels for VOCs at McAFB will not be specified for removal actions. Any residual contamination remaining after implementation of the SVE presumptive remedy will be considered when deciding on further response actions.

Section 4
SITE SELECTION METHODOLOGY

In order to select candidate sites for the application of SVE removal actions, two decisions need to be made: (1) whether or not site conditions will allow SVE to be effective in removing contaminants from the vadose zone, and (2) whether or not a removal action is warranted at the site. The SVE feasibility evaluation serves as an initial screening for sites that can be successfully treated with this technology, while the removal action evaluation is used to qualify, and perhaps prioritize, sites for removal action. The sequence of these evaluations is not important, and they may even proceed in parallel. However, both evaluations must result in affirmative responses for the SVE removal action to be put into effect. The site selection methodology is shown in figure 4-1.

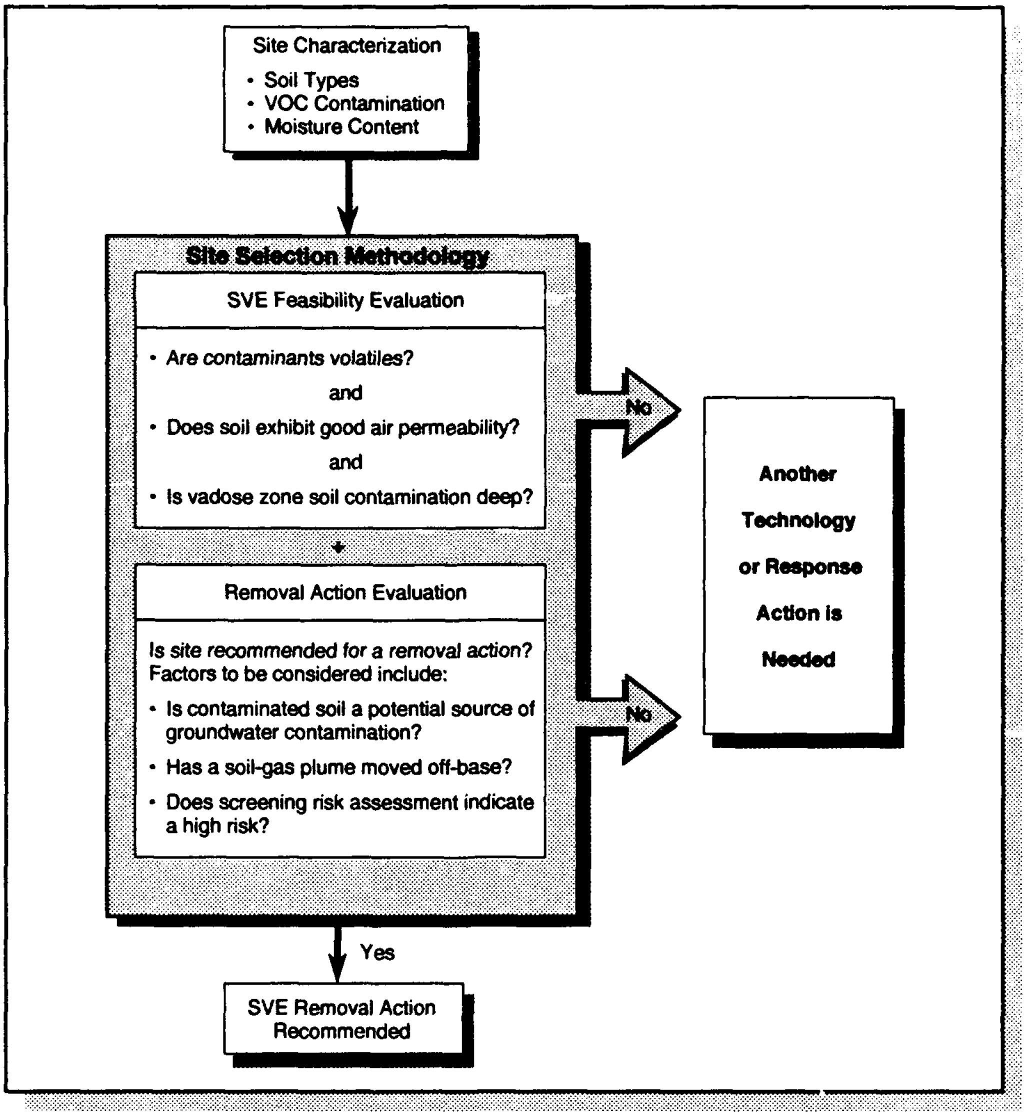

Figure 4-1
Site Selection Methodology

Section 4

Criteria for SVE Application

In order for the SVE process to be effective, the contaminants must be capable of volatilizing into the soil gas matrix, and the soil gas itself must be able to move freely to the extraction well. In practical terms, these constraints require that the contaminants be volatile compounds and soil to exhibit good air permeability. The chemical volatility can be measured either by Henry's Law constant or by the vapor pressure for specific substances. Soil gas movement is determined by the relative permeability of the soil, which is dependent upon soil structure and the degree of water saturation. In addition to these criteria, shallow soils (less than 5 feet deep) can be remediated by other means in a more cost-effective manner, and hence are not good candidates for SVE. Application of the criteria in the table below may be used to determine whether or not the SVE technology could be expected to be successful.

The following conditions should be met for application of SVE at McAFB:

Vadose zone contaminants are volatile.
- *Henry's constant > 0.001, or*
- *Vapor pressure >0.5 torr at 20°C*

Permeability of soils is adequate.
- *Air permeability of the soil > 10-3 darcies*
- *Water-filled porosity < 80 percent*

Contaminated vadose zone soil extends more than 5 feet below the surface.

Soil permeability information is not often available for a site, but hydraulic conductivity has been used as a surrogate parameter. It has been suggested that SVE can be successfully applied to soils having hydraulic conductivity greater than 10^{-6} cm/sec. According to a U.S. Geological Survey paper (Heath, 1987), sand, silty sand, and silts all have typical hydraulic conductivities greater than 10^{-6} cm/sec. Clay, however, has typical hydraulic conductivities below this level. Therefore, unless the soil under a site is predominantly clay, it should be amenable to SVE treatment.

Criteria for Removal Action

The NCP allows the Air Force to take any appropriate removal action if it determines there is a threat to public health or welfare or to the environment [40 CFR, 300.415 (b)(2)]. In making such a determination, the NCP specifies the consideration of eight criteria, but only two of these criteria are applicable at McAFB sites where SVE can be potentially implemented:

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- Actual or potential exposure to nearby populations, animals, or the food chain from hazardous substances, pollutants, or contaminants
- Actual or potential contamination of drinking water supplies or sensitive ecosystems

Based on the above general criteria, the following guidelines have been established for selecting specific sites at which removal of contaminants from vadose zone soils would be advisable.

Guidelines for Selecting Candidate Removal Sites

- *Source of existing groundwater contamination*
- *High threat for potential groundwater contamination*
- *Migration of soil gas plume off-base*
- *High risk indicated from risk screening assessment*

Groundwater characterized by high VOC concentrations may be expected to be overlain by vadose zone soils having high soil gas concentrations of these contaminants. In some instances, the movement of VOCs may be from the groundwater into the vadose zone soils, and in others, from a source in the vadose zone into the groundwater. In either instance, removal of the vadose zone VOCs would reduce the threat of exposure to these contaminants.

Soil gas investigations have indicated many areas where contamination levels are very high. For example, at IC 1 in OU B, up to 1,900 ppmv TCE, and over 6,900 ppmv PCE, have been found in soil gas. TCE and PCE concentrations as high as 3,500 μg/l and 370 μg/l, respectively, have been found in groundwater under IC 1. These high concentrations indicate that the soils in the vadose zone can serve as a continuing source of contamination to groundwater. Remediation of groundwater contamination cannot be efficiently achieved without addressing the source problems in the vadose zone. Therefore, sites at which there is a high degree of contamination in groundwater or vadose zone soils are appropriate candidates for a removal action.

Indications that a soil-gas plume has moved off-base is another reason to consider a site to be a candidate for removal action. Off-site workers and residents may be exposed to vapors migrating from the soil-gas plume, and soil-gas vapors might infiltrate buildings and crawl spaces, increasing the potential of exposure by inhalation. In off-base areas adjacent to OU D, both shallow and downhole soil gas samplings have found significant VOC concentrations. Total VOC concentration in soil gas near the water table has

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been measured to be 500 ppmv. Therefore, there is a potential threat to off-base populations. A removal action is warranted in this case to prevent further off-base movement of the VOC gas plume.

Risk screening can also provide candidates for a removal action. As outlined in the McAFB Risk Consensus Statement (MITRE, 1993), even a qualitative site screening could indicate a high risk associated with soil contamination, indicating that a removal action should be considered. Factors which may be considered include the level of contamination, the presence of acutely toxic substances, public concern, the location of receptors, and the connection to groundwater. The quantitative results of a screening risk assessment can also be used to indicate whether or not a site should be considered a candidate for a removal action.

Section 5
APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Section 121(d)(2)(A) of CERCLA specifies that Superfund remedial actions must meet any federal standards, requirements, criteria, or limitations that are determined to be legally "applicable" or "relevant and appropriate" requirements (ARARs). It also specifies that state ARARs must be met if they are more stringent than federal requirements.

CERCLA 121 requirements generally apply as a matter of law only to remedial actions. However, the NCP requires that ARARs be identified and attained to the extent practicable for removal actions (40 CFR 300.415[i]).

ARARs are generally placed in three categories: chemical-specific, action-specific, and location-specific. Chemical-specific ARARs define cleanup levels in the ambient environment, action-specific ARARs define performance and design standards for the action taken, and location-specific ARARs modify chemical- and/or action-specific ARARs to reflect the unique requirement of the location. The basewide SVE removal action will attain all ARARs to the extent feasible.

During the basewide removal actions, there will be multiple sites with SVE in operation. McAFB will consider the total cumulative impact from these activities when translating ARARs into system performance requirements and when evaluating the attainment of ARARs. For example, when setting emission levels protective of the human health, the base will consider the total cumulative impact from toxic emissions, including the expected emissions from proposed SVE systems.

In addition to ARARs, this section describes "to be considered criteria" (TBCs) that have been identified. TBCs include policy, guidance (not promulgated and not enforceable), and local regulations (not state or federal). Although not ARARs, TBCs provide additional information for defining cleanup levels that are protective of human health and the environment. They are not enforceable unless the base chooses them as performance standards.

Chemical-Specific ARARs and TBCs

Chemical-specific ARARs set limits on concentration of specific hazardous substances, pollutants, and contaminants in the environment where removal actions are being applied. These ARARs are applied to the chemical of concern in the designated media. Currently, there are no promulgated federal or state chemical-specific concentration limits or TBCs for VOCs in soil.

However, ARARs and TBCs in other media (air, groundwater, and surface water) may play a significant role in decisions involving the remediation of VOCs in soils. VOCs are generally considered to be mobile, and they may

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migrate from soils to air and water. Therefore, the need for remediation and the establishment of soil cleanup goals for VOCs will take into consideration ARARs and TBCs in other media, using an appropriate fate and transport model. Of particular concern is the potential impact on groundwater. The chemical-specific ARARs and TBCs listed in table 5-1 address this concern.

Action-Specific ARARs and TBCs

Action-specific ARARs set controls or restrictions on activities related to the management of hazardous substances or pollutants. Key action-specific ARARs for SVE have been identified for the Site S treatability study. When SVE removal actions are applied at McAFB, the performance of the vapor treatment system will comply with the following rules promulgated by Sacramento Metropolitan Air Quality Management District (SMAQMD).

SMAQMD Rule 202, New Source Review

Section 301 of this rule requires that new emission units apply Best Available Control Technology if there is a potential to emit pollutants in excess of specified levels.

Control levels for Best Available Control Technology:

Reactive organic compounds	*0 lbs/day*	*Mercury*	*0.55 lbs/day*
		Vinyl chloride	*5.5 lbs/day*
Nitrogen oxides	*0 lbs/day*	*Fluorides*	*16 lbs/day*
Sulfur oxides	*0 lbs/day*	*Sulfuric acid mist*	*38 lbs/day*
PM10	*0 lbs/day*	*Hydrogen sulfide*	*55 lbs/day*
Carbon monoxide	*550 lbs/day*	*Total reduced sulfur compounds*	*55 lbs/day*
Lead	*3.3 lbs/day*		
Asbestos	*0.04 lbs/day*	*Reduced sulfur compounds*	*55 lbs/day*
Beryllium	*0.0022 lbs/day*		

Section 302 requires "offsets" for criteria pollutants for any new emission unit if its operation will cause the total source emissions to exceed threshold levels.

Threshold levels for criteria pollutants:

Reactive organic compounds	*150 lbs/day*
Nitrogen oxides (NOx)	*150 lbs/day*
Sulfur oxides (SOx)	*150 lbs/day*
PM10	*80 lbs/day*
Carbon monoxide (CO)	*550 lbs/day*

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Table 5-1
Chemical-Specific ARARs and TBCs for Water

ARAR/TBC	Description
Porter-Cologne Water Quality Control Act (California Water Code Section 13304) [ARAR]	This section of the Water Code is applicable and authorizes the Regional Boards to require cleanup and abatement of discharges of waste into the waters of the state or discharge to land that have or threaten to result in discharges to waters of the state. The goal of Section 13304 is to attain background for the cleanups, but if background cannot be attained, the cleanup level must at least protect the beneficial uses of the water and comply with the plans and policies of the State and Regional Water Boards.
Water Quality Control Plan for the Central Valley Region [ARAR]	The Basin Plan establishes water quality standards including beneficial use designations, water quality objectives to protect those beneficial uses and implementation programs to meet the objectives, that apply statewide or to specific water basins. The beneficial uses of the groundwater in the vicinity of McClellan Air Force Base are agricultural, municipal, industrial, and domestic supply. For cleanup of groundwater, discharges of treated wastes, and the determination of concentrations of contaminants allowed to remain in-place, we will consider the maximum levels which are protective of the beneficial uses of the water(s).
State Water Resources Control Board Resolution No. 68-16 [ARAR]	The state policy is similar to the federal antidegradation policy, but has broader applicability as it applies to groundwater, as well as surface water. This Resolution has been incorporated into the Basin Plan which have been accepted by the Environmental Protection Agency (EPA) and is part of the Basin Plan's water quality standards. This policy is applicable if waste is left in place and has the potential to discharge to groundwater (not an inert waste).
State Water Resources Control Board Resolution No. 88-63 [ARAR]	This is an adoption of policy entitled "Sources of Drinking Water." This policy establishes what constitutes a drinking water source.
Discharges of Waste to Land 22 CCR, Chapter 15, 25 10(g), 2511(d), and Article 5 [ARAR]	This regulation contains provisions regarding the need to protect water resources by taking necessary monitoring, characterizing, and corrective action in response to releases to groundwater, surface water, or the unsaturated zone.
State Water Resources Control Board Resolution No. 92-49 [TBC]	This resolution outlines policies and procedures for investigation, cleanup, and abatement of discharges or potential discharges under Water Code section 13304 which authorizes the Regional Water Quality Control Board to require that these activities comply with the antidegradation policy.
A Compilation of Water Quality Goals [TBC]	This manual describes the process by which numerical values for water quality parameters and constituents may be selected to protect beneficial uses of groundwater and surface waters of California. It also contains numerical water quality goals for organic and inorganic constituents for various beneficial uses.
The Designated Level Methodology for Waste Classification and Cleanup Level Determination (by California Regional Water Quality Control Board, Central Valley Region) [TBC]	This report outlines a set of procedures that complements the process for classifying waste and setting cleanup levels for the protection of the public health and the quality of usable waters in California.

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The offset requirement for criteria pollutants is likely to be the most limiting ARAR for the basewide application of SVE because McAFB already exceeds the offset threshold levels for CO, SOx, and NOx. Therefore, offsets will be required for any emission of these pollutants, with the possible exception of CO.

SMAQMD Rule 402, Nuisance

This rule prohibits the creation oi a public nuisance, which includes unacceptable health risk. Thus, this rule applies to emissions of air toxins that pose an unacceptable health risk.

When determining the health risk, the cumulative effect of all toxic emissions from sources within the base will be considered, including the toxic emission from the proposed SVE application. A screening, or refined, risk assessment is required and will follow the SMAQMD guidance: "Permit Procedure Regarding Criteria for Calculating an Excess Cancer Risk to the Public Whom May Be Exposed to Carcinogenic Air Contaminants from New/Modified Toxic Air Emission Source." Depending on the estimated risk, it may be necessary to install the Toxic Best Available Control Technology (TBACT).

Two TBCs have been identified by the state to provide additional guidance on HCL emission and noise abatement. For HCL emission, in addition to being a toxic emission in the risk assessment, the levels set forth in Title 22, Section 66264.343 (b) shall be used as an attainment goal.

Attainment goal for HCl emission:

No greater than the larger of 4 lbs per hour

or

1 percent of the HCl in the stack gas prior to entering any pollution control equipment

The most noted non-toxic nuisance in the SVE system is the noise generated from electric motors and blowers. The noise abatement goal corresponds to the Exterior Noise Standards from the Sacramento City and County Noise Codes.

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At the base boundary, the noise level from the SVE system should not exceed the following:

	Standards (dBA)	
Cumulative period of time	**7 am-10 pm (Day)**	**10 pm-7 am (Night)**
30 min/hr	*50*	*45*
15 min/hr	*55*	*50*
5 min/hr	*60*	*55*
1 min/hr	*65*	*60*
Never to exceed	*70*	*65*

Additional action-specific ARARs are listed in table 5-2.

Table 5-2
Additional Action-Specific ARARs for McAFB

ARAR	Description
Air Emission Standards for Process Vents 22 CCR 66264.1030	The owner or operator of a facility with process vents associated with operations managing RCRA hazardous wastes* organic concentrations of at least 10 ppmw shall either: • Reduce total organic emissions from all affected process vents at the facility below 1.4 kg/h (3lb/h) and 2.8 Mg/yr (3.1 tons/year); or • Reduce, by use of a control device, total organic emissions from all affected process vents at the facility by 95 percent by weight
Air Emissions Standards for Equipment Leaks 22 CCR 66264.1050	Establishes standards for pumps, compressors, pressure relief devices, sampling connecting systems, valves or lines that contain or contact RCRA hazardous waste* with organic concentrations of at least 10 percent by weight.
Chemical, Physical and Biological Treatment 22 CCR 66265.400	Establishes requirements for general operation, inspections, and closure for treatment of RCRA hazardous wastes.*
Land Disposal Restrictions Waste Analysis 22 CCR 66268.7	Requires waste be tested to determine if it is restricted from land disposal.
Miscellaneous Treatment Environmental Performance Standards 22 CCR 66264.601	Requires a miscellaneous unit be located, designed, constructed, operated, and closed in a manner that will ensure protection of human health and the environment.

*RCRA hazardous wastes as defined in 22 CCR 66261.21; 66261.24; chapter 11, article 4

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Location-Specific ARARs

These ARARs establish additional restrictions on contaminant levels or activities in the environment and are triggered by the unique nature of site location or its immediate environment. They may function as chemical-specific ARARs or action-specific ARARs. Examples of locations that require special consideration include floodplains, wetlands, historic places, and sensitive ecosystems or habitats. If the proposed site for SVE removal action is located in or near any of these locations, precautions need to be taken to ensure the compliance of the appropriate location-specific ARARs to the maximum extent practicable.

Potential location-specific ARARs are summarized in table 5-3. It is unlikely that any of them will pose a major compliance problem, considering the focus of the basewide SVE removal action and the nature of SVE technology. First, SVE removal actions are focused on "hot spots" of VOC contamination in soils. Hot spots are generally areas where hazardous wastes have been previously disposed of through trenching, burial, or deposition. Such areas will have been subjected to a high degree of disturbance through excavation activities. Given the amount of previous activity, it is unlikely that any cultural resources would remain at areas targeted for remediation. Secondly, SVE causes minimal disturbance to land. It is unlikely that it will alter any water body, affect wetlands, or affect the function of any floodplain. Third, the operation and design of an SVE system is very flexible, allowing modifications be made to address most potential concerns. The system can consist of trailer-mounted or skid-mounted modules. To ensure quiet operation, mufflers can be added to the intake and outlet lines, and the complete motor-blower assembly can be placed in acoustic enclosures.

Location-specific ARARs will be identified during site-specific applications and the design document for each site will describe how the site will comply with the ARARs. For example, when a candidate site for SVE is identified, evaluation will be made to determine if the proposed site is a critical habitat for endangered or threatened species, and if the property is eligible for protection under the National Historic Preservation Act or the Archaeological and Historic Preservation Act. If any of the potential ARARs applies to the candidate site, precautions will be taken in the design, construction, and operation of the SVE system to ensure compliance.

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Potential ARAR	Location	Requirement
National Historic Preservation Act Section 106 (16 U.S.C. 470 et seq.); 36 CFR Parts 800 and 60	Property included in or eligible for the National Register of Historic Places	Implement the controls to minimize harm to National Register properties or eligible properties.
Archaeological and Historic Preservation Act (16 USC Section 469 to 469c-1); 36 CFR Part 65	Within areas where action may alter the terrain and cause irreparable harm, loss, or destruction of significant artifacts	Take measures to preserve historical and archeological data that might be lost as a result of alterations of the terrain.
Endangered Species Act of 1973 (16 USC 1531 et seq.); 50 CFR Parts 200 and 402	Critical habitat for endangered or threatened species	Consult with the Department of Interior. Avoid jeopardizing the continued existence of listed endangered or threatened species; also restrict the modification of their critical habitat.
Fish and Wildlife Coordination Act (16 USC 661 et seq.); 40 CFR 6.302	Areas where activities may modify stream or river	Consult with the Fish and Wildlife Service prior to any action that would alter a body of water of the United States. Need to develop measures to prevent, mitigate, or compensate for any remedial action-related losses to fish or wildlife resources.
Executive Order 11988, Floodplain Management	Floodplain	Avoid adverse effects, minimize harm, restore and preserve the natural and beneficial values within a floodplain.
Executive Order 11990, Protection of Wetlands	Wetlands as defined by Executive Order 11990	Minimize the destruction, loss, or degradation of wetlands.
Location Standards 22 CCR 66264.18	Fault and floodplain	Shall not site hazardous waste facility to be within 61 meters (200 feet) of a fault which has had displacement in Holocene time. Shall design facilities to prevent washout of any hazardous waste if located in a 100-year floodplain.
Facility Security 22 CCR 66264.14	California	Prevent the unknowing entry, and minimize the possibility for the unauthorized entry of persons or livestock.
Facility Location 22 CCR 66270.14(b)(ii)	California	Need to demonstrate compliance with the seismic standard and to identify whether the location is within a 100-year floodplain.

Table 5-3
Potential Location-Specific ARARs for McAFB

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SVE TECHNOLOGY DESCRIPTION AND COST ESTIMATE

This section describes a baseline SVE system as it would typically be applied at McAFB, along with some options for its design and construction. Also included is a planning-level cost estimate for the baseline system, with the realization that exact costs will depend on several site-specific factors that cannot be generalized or predicted in advance.

Baseline SVE System Configuration

Soil vapor extraction technology relies on the flow of air moving through subsurface soil, which is induced by an applied vacuum, to volatilize contaminants from the soil. The air and volatilized contaminants are carried to the surface through extraction wells. Contaminant destruction or separation is carried out in equipment located at the surface. SVE is enhanced by the highly permeable subsurface conditions such as appear to exist under much of McAFB. High soil permeability permits high air flow rates which effectively desorb contaminants from soil.

In its general form, the McAFB baseline SVE system consists of the following:

- *Extraction wells extending through the subsurface contamination*
- *A collection system that connects vapor flow from each well to the vacuum system*
- *A vacuum system, comprised of one or more electrically powered blowers, to produce the vacuum required to run the SVE system*
- *An off-gas treatment system to remove or destroy volatile contaminants in the vapor stream prior to atmospheric release*

Figure 6-1 illustrates the major elements of the baseline SVE system.

Extraction Wells

Soil vapor extraction wells are typically constructed of slotted PVC pipe extending through the unsaturated zone to intercept subsurface zones of soil contamination. The construction of vacuum extraction wells is identical to that of groundwater wells. Well diameters are typically four inches. At McAFB, well depths may extend to between 80 and 90 feet, a level that corresponds to a few feet above the average depth to groundwater. The number of extraction wells and the screened interval are determined by soil permeability and the extent of contamination. Both of these design parameters are currently being investigated at McAFB. Recent experience at OU B indicates that radius of influence is in excess of 150 feet (Radian, 1993).

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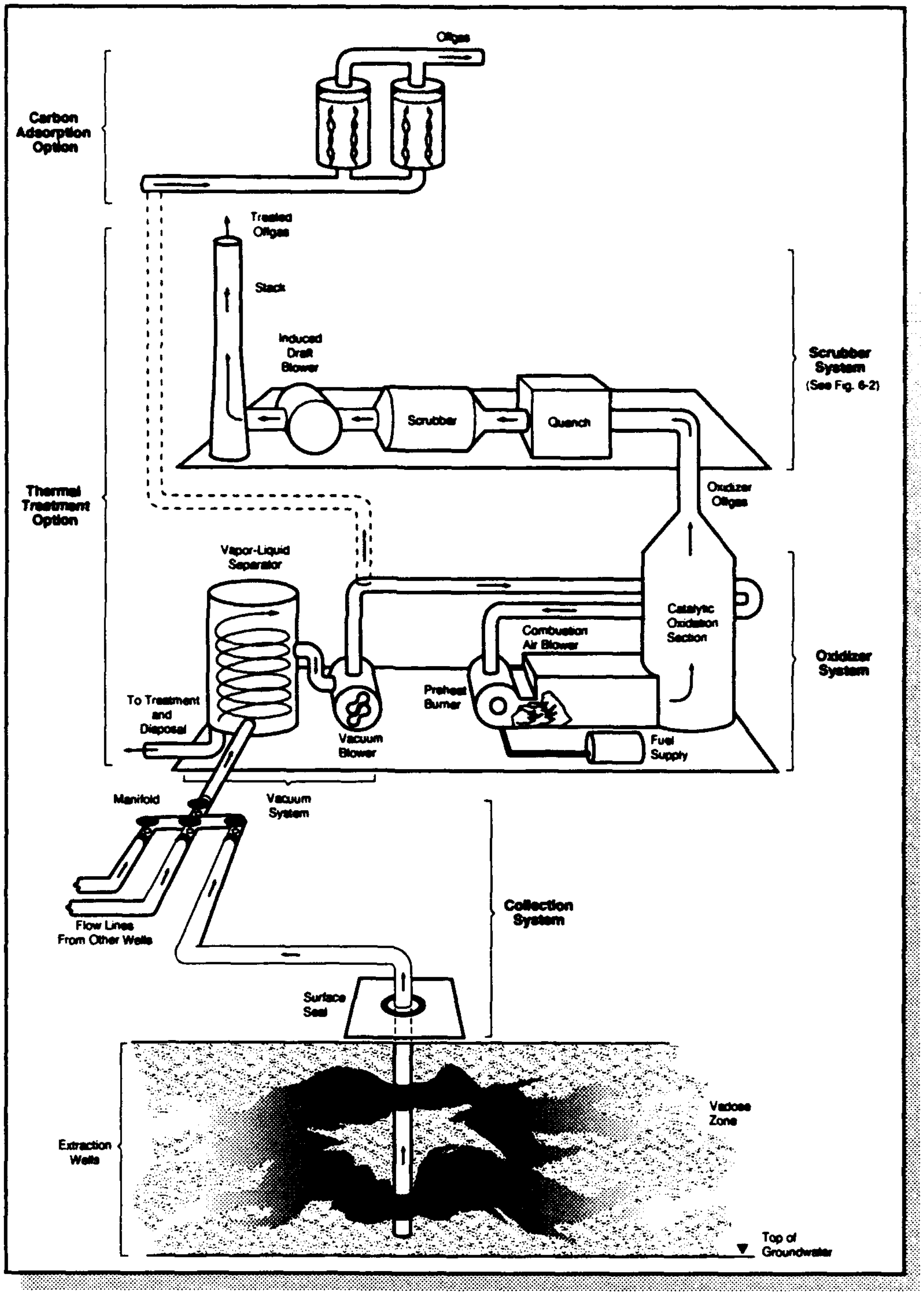

Figure 6-1
Baseline SVE System

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Collection System

The vapor collection system consists of piping and valves that connect the extraction wells to the vacuum system. Flows from each individual well in the extraction well field are controlled by valves at each well head. Pipes are run from each well to a manifold assembly at or near the vacuum system, which combines flows and provides valving to control and isolate individual collection system lines as needed. The vapor collection system includes provisions for monitoring pressure, temperature, flow rate, and extracted vapor composition.

In areas of McAFB that are away from traffic and other interferences, collection piping may be run along the surface to the manifold connection point. In areas of active land use (e.g., in and around operating facilities), it is usually desirable to place collection lines in shallow trenches.

Vacuum System

The vacuum system provides the motive force to draw soil gas from the soil through extraction wells and to collect the extracted vapor streams. Its principal components are vapor/liquid separators and one or more electrically powered blowers. Extracted vapors are drawn from the collection system manifold to an vapor/liquid separator where any entrained liquids are removed from the vapor stream. Liquids that accumulate in the separator are collected for treatment on-base at the McAFB Industrial Waste Treatment Plant or may be shipped off-base for disposal elsewhere. Vapors extracted from the soil are usually saturated, and condensate removal is necessary to protect the vacuum blowers. The dewatered vapor stream passes through a filter that removes entrained particulate matter prior to the vacuum blower inlet. Applied vacuums typically range from 20 to 30 inches of water, so centrifugal or positive displacement blowers may be chosen for most applications. Multiple vacuum blowers in a single SVE system will be used to enhance reliability and permit operating flexibility when individual wells are shut down due to water infiltration, or when extraction is being conducted cyclically.

Off-Gas Treatment System

Before the exhaust from the vacuum system is released into the atmosphere, the volatile contaminants in the extracted vapor stream must be either removed or destroyed. The two primary methods for accomplishing this are (1) adsorption and (2) destruction by catalytic vapor oxidation.

Adsorption

Volatile organic compounds can be removed from the SVE exhaust stream by adsorption on activated carbon. Vapor phase carbon adsorption utilizes highly porous carbon granules as a medium for capturing the VOCs in SVE exhaust

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gas streams. Carbon adsorption systems typically consist of one or more sealed vessels filled with granulated carbon, connected in series and/or parallel, and operating under atmospheric or positive pressure. The primary advantage of carbon adsorption is that there are no combustion processes involved, and therefore no associated emissions of particulates, hydrochloric acid, nitrogen oxides, or other combustion by-products.

Vapor phase carbon adsorption is most commonly used when total VOC concentrations are in the 100–200 ppm range and would be appropriate for the SVE off-gas streams from McAFB. Limitations of carbon adsorption (as well as other adsorption technologies) arise from the fact that, while it removes contaminants, it doesn't destroy them. The activated carbon in an adsorber must be periodically replaced and the carbon regenerated, usually at an off-base facility permitted for this activity. Therefore, operating costs for carbon adsorption are primarily the cost of carbon replacement and regeneration. Carbon adsorption systems also are adversely effected by high vapor moisture levels and high temperatures.

Catalytic Oxidation

Based on results from the Site S Treatability Investigation, catalytic oxidation has been identified as the best available control technology (BACT) for destruction of volatile contaminants at the high concentrations that typically occur during SVE extraction (CH2M Hill, 1992). Catalytic oxidation uses a catalyst bed for initiating oxidative destruction of VOCs in the SVE vapor stream. The catalyst facilitates the oxidation process, but is not consumed by it. Again, from results of Site S operations, McAFB has decided to use base metal catalysts (e.g., oxides of manganese or iron) to lower costs. The Site S unit uses a fluidized bed catalyst, where catalyst-coated ceramic pellets are fluidized, or suspended, by the motion of the vapor stream through the catalyst bed. Recent performance data indicate the attainment of VOC destruction efficiencies above 99 percent.

In currently available catalytic vapor oxidation units, the volatile contaminants must be preheated to the catalyst's activation temperature to sustain the oxidation process. The catalyst at Site S requires preheating to 750°F, which is accomplished with a natural gas or propane-fired preheat burner located in a combustion chamber upstream of the catalyst bed. Combustion air is fed into the system to maintain the total concentration of flammable contaminants at less than 25 percent of the lower explosive limit to prevent overheating and damage to the catalyst. The maximum operating temperature of the catalyst is approximately 1,250°F.

Catalytic oxidation produces nitrogen oxides, a class of gaseous pollutants that must be controlled to meet regulatory requirements. In the Sacramento

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area and at McAFB, new nitrogen oxide emissions must also be offset by removal or reduction of nitrogen oxide emissions from other sources in the region. An advantage of catalytic oxidation is that in the temperature range in which most systems operate, nitrogen oxide production is minimal, especially in comparison with flame-based thermal oxidation. McAFB is currently participating in an offset program to eliminate nitrogen oxide emissions from other sources.

All thermal oxidation systems, including catalytic ones, may yield products of incomplete combustion, including dioxins. The catalytic system will be operating at sufficiently high temperature and flow rate to ensure high destruction efficiency and proper mixing of the catalytic media and to minimize the production of dioxin. Exhaust gas treatment system operations at McAFB will be monitored. The use of an acid gas scrubber (see below) will also help ensure that particulate matter, on which any products of incomplete combustion would be condensed, is removed from the exhaust stream.

Catalytic oxidation of chlorinated organic compounds produces HCl vapors. At McAFB it will be necessary to remove the HCl through use of a scrubber installed downstream of the catalytic oxidizer. Figure 6-2 illustrates the principal components and functions of a scrubber system. The scrubber consists of two stages: a wet quench venturi scrubber to initially cool the exhaust gases from 1,000°F to about 350°F and capture some of the HCl, and a second countercurrent wash stage using caustic solution to remove the remaining HCl. Scrubbers on SVE systems have achieved HCl removal rates above 99 percent. Scrubber auxiliaries include a caustic solution supply system and circulating pump, a brine bleed discharge system that removes and treats excess brine from the scrubber sump, and an induced-draft fan that draws treated vapors from the scrubber and discharges them through the stack. An additional scrubber auxiliary is a three-tier blowdown treatment process: clarification, filtration, and activated carbon polishing. This waste treatment system is more extensive than usual because of the concern over dioxin. Excess scrubber brine, which accumulates in the scrubber sump, is drawn off automatically, filtered, and passed through an activated carbon adsorber and measured for dioxin before discharge to the McAFB Groundwater Treatment Plant (GWTP). Sediment will be tested for dioxin before being sent to registered landfill for disposal. Carbon may be regenerated on-site if the dioxin concentration is low in the inflow.

Baseline SVE Design Options

The baseline SVE system described above is generic. Although all of the general system functions will be the same across McAFB sites, adaptations of the baseline design will be necessary. Each SVE removal action site is

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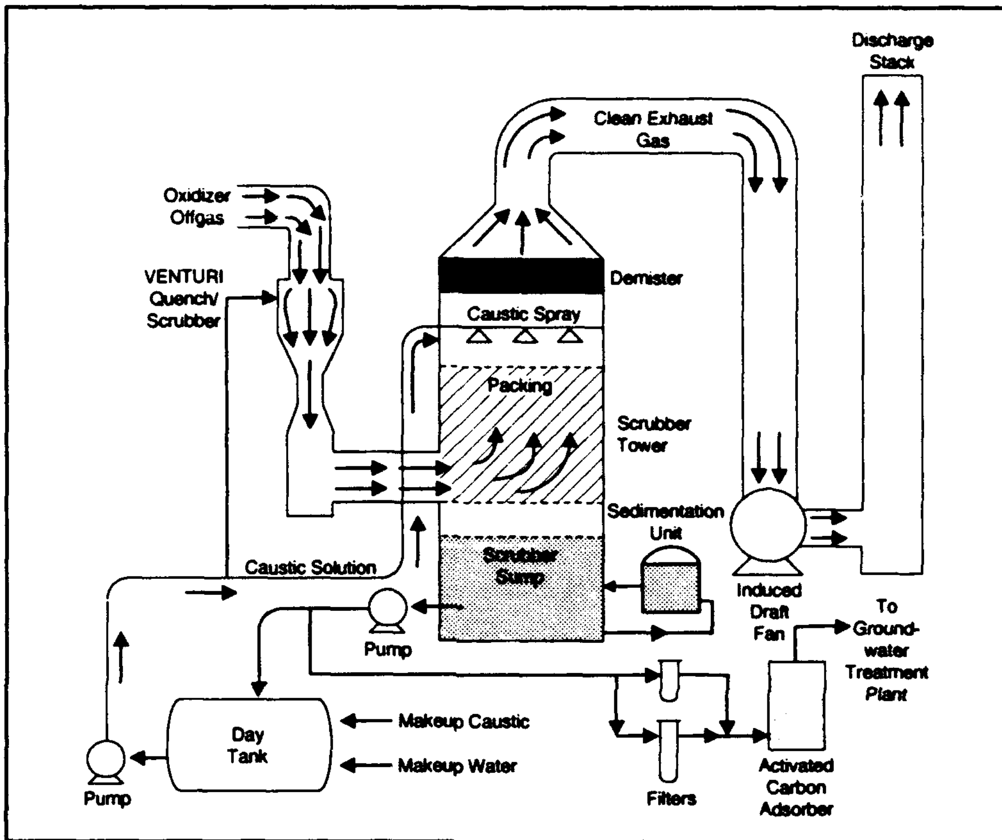

Figure 6-2 *Scrubber System Simplified Schematic*

unique, with variations in site size, number and location of extraction wells, subsurface conditions, amount of contaminant, and surface operating environment; each of these variations imposes constraints on the baseline design approach. The base is conducting short-term pilot tests to identify site-specific design parameters, and it is considering system modularity and mobility, as well as noise abatement.

SVE Pilot Tests

McAFB is conducting limited-scale, short-duration SVE pilot tests to provide vital information for the design and implementation of SVE removal actions at McAFB.

A pilot test is a short duration, limited-scale vacuum extraction run in a single test well, around which additional wells have been drilled at some regular spacing for vacuum measurement. Results of these tests provide information on vacuum performance vertically across different soil units and horizontally at varying distances from the extraction well, all under actual site conditions.

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Information on the composition and concentrations of VOCs obtained during pilot tests is vital in guiding the selection and sizing of the vacuum and vapor treatment systems. Soil gas flow rates, measured at various distances from the extraction well and at various applied vacuums, are used to identify an economical operating vacuum and a well spacing that will provide a flow rate capable of remediating a site within a reasonable time. The pilot test identifies reasonable design parameters that can be modified to enhance performance.

Vendors of SVE equipment and services offer economical pilot test capabilities to support project design and implementation. These include quick-turnaround SVE testing, where portable vacuum and vapor treatment systems are mobilized to each site, and tests run for 8- to 24-hour intervals. Mobilization and demobilization is accomplished in as little as 3 hours, and the vapor treatment systems are often pre-permitted in the states and localities in which vendors offer these services. Multi-well pilot tests are typically in the $30,000 range, including all analyses and reporting of results.

SVE pilot tests can be valuable in implementing SVE; the data and experience these tests contribute can significantly reduce project costs and uncertainty. Operations conducted in pilot tests are under actual field conditions, so cost and time requirements for site characterization studies can be proportionately reduced.

System Modularity and Mobility

An important consideration in planning McAFB SVE removal actions involving multiple-site projects is the development of a standardized modular design approach for the SVE vacuum and off-gas treatment systems. Modularity enhances portability of these systems by using trailer-mounted and skid-mounted system modules, and also enhances the interconnectivity and compatibility of all components. For example, utility hookups, instrumentation and control connections, and piping connections should be standardized to allow system modules to be mobilized quickly between various SVE removal action locations at McAFB. Other components, such as the scrubber, can also be configured for easy mobilization between those sites where it is to be used.

Modularity also supports the concept of a two-phased off-gas treatment approach: use of catalytic oxidation in early project stages while VOC concentrations are at maximum levels, and then quick changeover to a carbon adsorption treatment module during SVE close-out, when VOC concentrations are sufficiently low. The thermal modules can be disconnected and mobilized to the next site, and a carbon adsorption module installed in its place. Standardization of system interfaces facilitates these changeovers.

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Although the vacuum and off-gas treatment system have been discussed separately, they are frequently designed, manufactured, and sold as integrated units by vendors of SVE systems. Smaller systems, such as those with total capacities below 500 scfm, are available as single, trailer mounted units (figure 6-3). Mobilization of these units consists of making piping and utility connections, and can be accomplished in as little as three hours. These portable units are used for pilot tests and can be moved quickly and inexpensively to different site locations for testing operations. Larger systems, such as those in the 2,000 scfm and larger capacity range, can be supplied either as portable units (e.g., on multiple trailers), or manufactured on one to three skids. Mobilization consists of locating the skid(s) on a prepared concrete slab or other suitable foundations and making utility, piping, and instrumentation hookups.

Noise Abatement

Operation of SVE systems creates some noise, principally from electric motors and vacuum blowers. Several measures can be taken to reduce the noise-related impact at McAFB. Prior to project implementation, SVE removal action sites can be surveyed and locations for vacuum and off-gas treatment systems

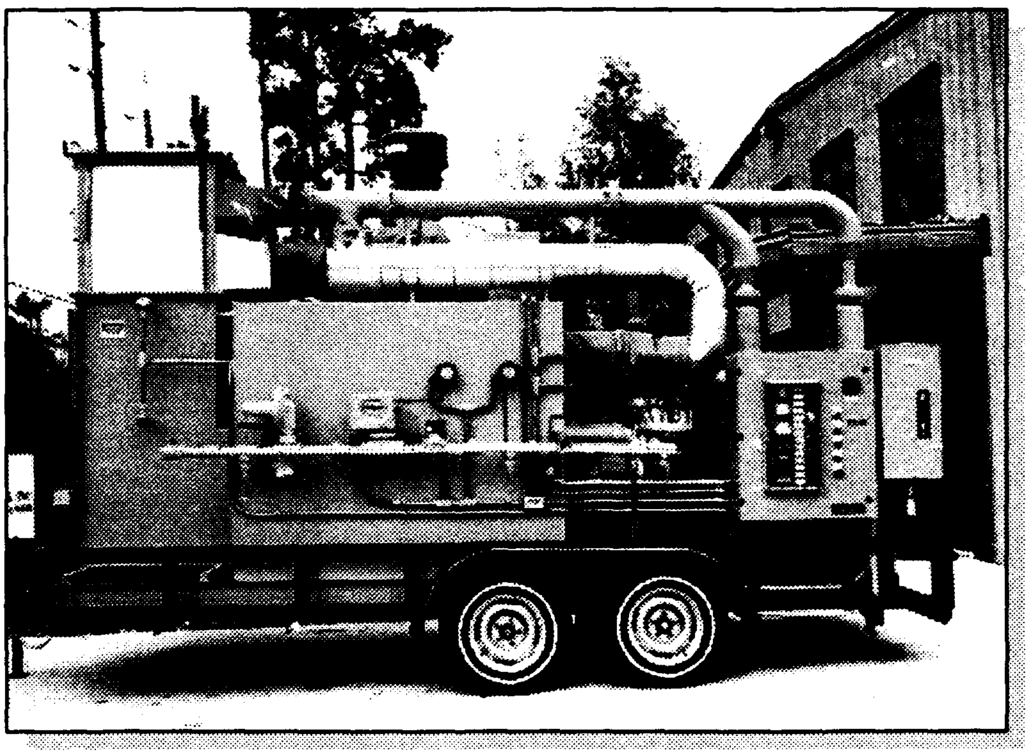

Figure 6-3
Trailer-Mounted SVE Unit

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chosen to minimize impacts on adjacent noise-sensitive areas. Engineering noise controls available for SVE system include mufflers on vacuum blower intake and discharge lines, acoustically-deadened enclosures for electric motors and blowers, and construction of acoustic barriers and/or earth berms around the equipment location.

Itemized SVE System Costs

Table 6-1 lists generic unit costs for baseline SVE system components, and the design basis required to estimate the costs for a typical removal action. The cost information was obtained from vendors of SVE equipment and from the installation of SVE equipment for the Site S Treatability Investigation.

The major factor affecting SVE system costs is the emissions control device used to eliminate contaminants from the SVE discharge. The emissions control equipment is nominally designed to process a gas flow rate of 2,500 scfm from the SVE system, since that size would be large enough to accommodate most removal actions at McAFB. Use of a standardized configuration facilitates equipment design and procurement, and is essential for installing transportable equipment that may be used at several sites. The equipment costs listed in table 6-1 include mounting the equipment on trailers that can be moved from site to site. Contaminant concentrations entering the emissions control equipment when the SVE systems begin operating are assumed to be at concentrations of 3,000 ppmv of chlorinated organic compounds and 5,000 ppmv of petroleum hydrocarbons. These values are used to construct the mass and energy balance that provides the design basis for estimating monthly operating costs.

Activated carbon can be used to control emissions when contaminant concentrations in the soil gas become less than 200 ppmv, replacing the catalytic oxidizer and scrubber. The capital cost of a trailer-mounted carbon adsorption system is approximately $120,000, with a carbon inventory sufficient to operate for approximately one month. The cost to replace the spent carbon is approximately $80,000 per month. Carbon consumption is approximately 40,000 pounds per month at a flow rate of 2,500 scfm and influent concentration of 200 ppmv, and decreases proportionally as the concentration decreases.

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Item	Design Basis	Unit Cost	Item Cost
Site Preparation:			
Gas Connection	750 feet of 2 inch polyurethane line	$7.50/foot	$5,600
Electrical Connection	1000 feet of buried 4 inch conduit	$5.00/foot	5,000
Transformer	12kv to 440 v unit	$13,000	13,000
Water Connection	1000 feet of buried 2 inch PVC pipe	$14.00/foot	14,000
Grading and Equipment Platform	3000 sq. feet of subgrade and concrete	$6.00/sq. foot	18,000
Well Installation	9 wells at total depth of 800 feet	$75.00/feet of depth	60,000
Equipment:			
Vacuum blowers	4 blowers rated 500-800 scfm @ 7-12 inches of Hg	$17,000	$68,000
Air-Water Separators	2 units, 12000 & 2000 scfm rated @ 18 inches of Hg	$4,000	8,000
Manifold and Piping	1000 feet of 4-8 inch PVC pipe, fittings and support	$30.00/foot	30,000
Emission Control System	Catalytic oxidizer w/scrubber	$355,000	355,000
Engineering	10% of site and equipment cost		57,700
Mobilization	10% of site and equipment cost		57,700
		Total Cost:	$692,000
Operation and Maintenance:	90% uptime, 648 hours per month		*Monthly Operating Cost:*
Natural Gas	2425 scfh	$3.50/1000 scf	$5,500
Electricity	105 kw/h	$.075/kWh	5,100
Water	617 gph	$1.00/1000 gal	400
Scrubber Chemicals	254 pph	$350/ton	28,800
Waste Disposal	500 gph	$3.00/1000 gal	1,000
Testing and Monitoring	1 stack test per month, 9 well analyses per month	$2,500/sample	25,000
Operating Labor	90 hrs for 2 part-time techs and part-time sample collector	$70/hour	6,300
Reporting	1 monthly operations report and prorated summary report	$6,000/month	6,000
		Total Monthly Operating Cost:	$78,100
		Total Annual Operating Cost:	$937,200

Table 6-1
Baseline SVE Cost Estimate

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The following conclusions can be drawn from the cost data:

- The total project cost for a removal action operating for one year is approximately $1 million.

- Scrubbing hydrochloric acid more than doubles both the equipment and operating costs of catalytic oxidizers.

- At low VOC concentration, the cost of operating a carbon adsorption system to control emissions is comparable to that of a catalytic oxidizer. It should be noted that carbon adsorption offers the advantage of not generating any combustion byproducts, such as hydrochloric acid or nitrogen oxides.

Section 7
SVE SYSTEM ENHANCEMENTS

Enhancements and modifications to the baseline SVE approach may be required at some McAFB removal action sites to improve performance. The term "enhancement" is defined to mean any substantial modification of the baseline system at any site, beyond the simple design modifications described in section 6. These enhancements may include the following:

- Improvements to vapor extraction efficiency
- Integration of SVE with other remedial actions, including groundwater remediation
- Use of a different off-gas treatment system

All such enhancements to the baseline design are considered to be within the scope of the SVE presumptive remedy, which refers to the general process of extracting vapors from the subsurface for aboveground treatment.

The following subsections summarize system enhancements that may be applied to SVE removal actions at McAFB.

Extraction Efficiency Enhancement

This category of system enhancements includes methods for increasing air flow through the subsurface and for increasing the rate of volatilization of organic contaminants into the subsurface vapor stream.

Hot air injection is the injection of preheated, compressed air into wells drilled or converted for this purpose. In its simplest form, a portable diesel or a stationary electric air compressor is used to supply pressurized air through a distribution system to injection wells. In some cases, the temperature increase of the air due to compression is sufficient to increase volatilization. In others, the compressed air stream may be heated by passing it through a pressurized, fired air-to-air heat exchanger. This approach is costly due to the difficulty in heating compressed air (high equipment and energy costs).

Passive air injection is a variation in which wells are simply left open to atmospheric pressure. Passive wells may be used to isolate a specific site from surrounding contamination sources, since the net effect of a group of passive wells is to break the vacuum induced by extraction wells.

Steam injection is another means for increasing the volatilization of organic contaminants in the subsurface. A steam generator (usually a gas- or oil-fired boiler) is used to produce steam for injection through wells. Two problems

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associated with this approach are the high cost of energy and the introduction of condensate (liquid water condensed from the steam) into the subsurface, which may adversely impact soil permeability.

SVE Integration with Other Remedial Actions

Included in this enhancement category are integrated groundwater remediation techniques—dual extraction and sparging—and bioventing.

Dual extraction, sometimes called two-phase vacuum extraction, is the simultaneous extraction of volatile contaminants from groundwater and unsaturated soils through application of high levels of vacuum. The principle of operation is illustrated in figure 7–1. The primary difference between dual extraction and the more conventional SVE system operation is the vacuum level, which can be up to ten times higher in dual extraction. Vacuums of up to 29 inches of mercury would be used in dual extraction; this would greatly increase gas velocities in the extraction well, thereby promoting high levels of liquid entrainment (free product and groundwater) in the induced two-phase flow. Higher vacuums also increase volatilization and separation of organic contaminants from the soil and groundwater.

Advocates of this approach claim that it is possible to extract contaminants as free product, as well as from soil and water, all within the same well. Separate wells and collection systems for free product, soil vapor, and groundwater are not required.

Disadvantages of this technique stem from the high vacuums required and from the need for an integrated liquid treatment and disposal system. Dual extraction systems require use of liquid seal vacuum pumps, which are more costly and consume more energy than vacuum blowers used in other SVE systems. The higher vacuum also necessitates more robust piping systems and additional maintenance to prevent vacuum leaks throughout the system. Dual extraction systems produce larger volumes of liquids, including groundwater, and phase separators of sufficient capacity must be incorporated into the system. The use of seal water in the vacuum pump also requires incorporation of a second liquid-vapor separator after the vacuum pump.

Sparging is a variation of air injection in which compressed air is injected into the zone of groundwater saturation during SVE. As a result, an in-situ air stripping of volatile contaminants from the upper groundwater levels takes place, and the volatilized substances are drawn upward toward the vacuum extraction well. Sparging requires separate injection wells drilled into the contaminated aquifer and a supply of compressed air for each well.

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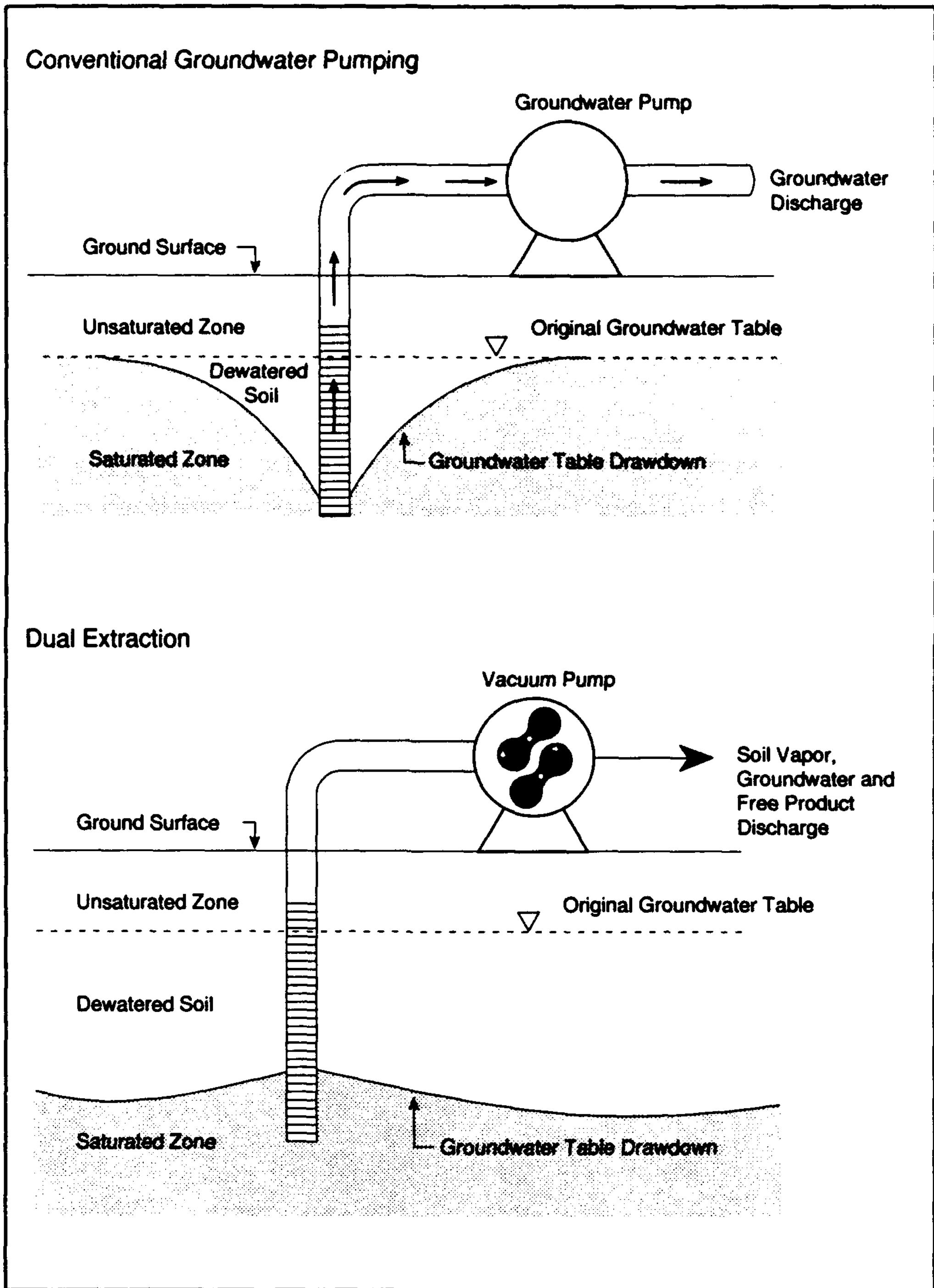

Figure 7-1
Principle of Dual Extraction

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Bioventing promotes aerobic microbial degradation in the unsaturated zone by supplying oxygen through injected air or vacuum-induced air flow. The air flow for bioventing is generally smaller than for the SVE system. Increased aerobic biodegradation has been observed on many SVE projects and has accounted for as much as 50 percent of the VOC removal rate. Biodegradation is most effective for non-halogenated compounds, and is less effective for chlorinated VOCs. Currently, there is an Air Force-wide effort to test the effectiveness of bioventing for sites with fuel contamination. Future efforts may expand to address chlorinated VOCs.

Alternative Off-Gas Treatment

As described in section 6, the baseline off-gas treatment approach at McAFB uses catalytic oxidation and carbon adsorption in two successive phases. Other treatment alternatives will be evaluated for application at McAFB, including variations of the thermal oxidation and adsorption methods. Of particular interest are alternatives that will minimize or eliminate NOx production.

Electron beam destruction uses the directed energy of an electron beam source to cause the breakdown and oxidation of organic contaminants in the off-gas stream. Advantages of the system include its low operating temperature, which greatly reduces the potential for nitrogen oxide production. As with other thermal methods, an acid gas scrubber is required to capture HCl produced from the breakdown of chlorinated organic contaminants. Electron beam systems are considered developmental and additional testing is required to determine their feasibility for application to full-scale SVE systems. McAFB has completed bench-scale testing of an electronic beam system known as ZAPIT. The destruction removal efficiency for gas streams with multiple compounds was found to be lower than for streams with a single component. The pilot test originally planned at McAFB has been postponed until after the base reviews the performance of a prototype ZAPIT application at another location. The base is also monitoring performance of other systems for future consideration.

Low temperature catalytic oxidation refers to new methods where organic contaminants are catalytically oxidized, some at temperatures below 300°F. Since this is essentially a non-combustion technology, advantages of this procedure are the elimination of nitrogen oxide generation and low energy costs. To date, developmental systems have required enrichment of the vapor stream feed with ozone to promote the oxidation process and also, in some methods, use of an ultraviolet light source to accelerate the catalytic process.

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Resin adsorption is an alternative to activated carbon in which synthetic resin materials provide the adsorption medium. An example of this technology, Purus PADRE, is currently being evaluated at Site S for potential use at McAFB. This system offers two potential advantages over a conventional carbon adsorption system: (1) the adsorbtion matrix can be conveniently and economically regenerated many times onsite; and (2) the adsorption matrix has a slightly higher adsorption capacity and hydrophobicity. As with a carbon adsorption system, this resin does not have good adsorption capacity for vinyl chloride. Because of the potential presence of vinyl chloride, the resulting off-gas will be treated by the catalytic oxidizer for destruction. When the resin adsorptive capacity is reached, soil gas will be diverted to a similar, parallel unit.

Following the adsorption bed switchover, the saturated off-line resin bed will go through the desorption cycle of heating and flushing with an inert purge gas (nitrogen). Then, the volatilized contaminants will be condensed to liquids through a chiller/condenser system. The remaining gas will be vented to the off-gas manifold system upstream of the adsorption unit, where it will be mixed with the untreated soil vapor. The condensate will be collected on-site in a storage tank and transported off-site daily for disposal using smaller drums. The condensor and condensate storage tank will be vented to the off-gas manifold system upstream of the adsorption unit.

Section 8
EVALUATION PROCESS

Each SVE removal action will be reviewed periodically to determine if it meets the principal objective for the removal action—early risk reduction by removing a significant quantity of VOCs from soils in the vadose zone, intercepting an exposure pathway, or preventing additional flux to groundwater. As indicated in table 8-1, this can be done by tracking the cumulative VOC mass removed, monitoring the change in the soil gas plume, and monitoring the change in groundwater concentration. The reduction in risk as a result of these changes can be estimated by using the screening risk assessment methodology described in the McAFB risk assessment consensus statement (MITRE, 1993). Also needing evaluation is ARAR attainment, except for ARARs pertaining to soil cleanup levels.

McAFB extends the scope of evaluation far beyond meeting the primary objective. The reason for the additional evaluation is that the basewide SVE removal action is the linchpin to a successful basewide SVE remedial action at the base. As illustrated in figure 8-1, basewide SVE removal actions generate cost and performance data, which are evaluated to identify design and operational changes and to establish a basis for final cleanup levels. Table 8-1 outlines an approach that will ensure consistent accumulation and tracking of experience from the basewide SVE removal action.

A detailed description of the sampling plan will be presented in the SVE design document and work plan. The evaluation process and the results of the evaluation eventually will be captured in the decision support document for the basewide SVE ROD.

Information from the basewide SVE removal action is critical for the following activities:

- *Defining efficient and effective SVE system design*
- *Setting realistic VOC cleanup levels*

The performance of SVE systems is most frequently measured by tracking the mass removal rate with time. Figure 8-2 shows a typical curve, which exhibits an exponential decrease of mass removal rate with time. Large masses of contaminant typically are removed during initial SVE system operation, and smaller, relatively constant masses of contaminant are removed during later stages of operation. The duration of the initial conditions and the rate of change depend on the characteristics of the individual site.

After contaminant removal rates level off, enhancements to improve the efficiency of the SVE system may be considered. Examples of enhancements

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Evaluation Areas	Elements
Removal Action Objectives	• Determine amount of contaminants removed from soil • Monitor changes in VOC soil gas in soils • Monitor changes in groundwater concentration downgradient • Estimate risk reduction using screening risk assessment methodology • Ensure compliance with ARARs, except for those pertaining to soil cleanup levels
Effective and Efficient SVE System Design	**Site Characterization** • Compare SVE performance at both well-characterized sites and incompletely characterized sites • Evaluate effectiveness of integrated sampling and remediation at incompletely characterized sites **Extraction System** • Determine effective well spacing and screened intervals • Determine and evaluate the effectiveness of enhancements as necessary **Aboveground Units** • Determine whether a standard transportable equipment configuration is practical • Evaluate emission control equipment options to meet regulatory requirements at the low estimate cost • Determine effective well spacing and screened intervals • Evaluate whether use of adsorbents for emission control is advantageous • Determine and evaluate system improvements as necessary
Cleanup Level	• Evaluate the accuracy of removal action cost estimates • Determine major factors affecting SVE performance; consistent performance would eliminate the need for predictive modeling

Table 8-1
Summary of Evaluations

Section 8

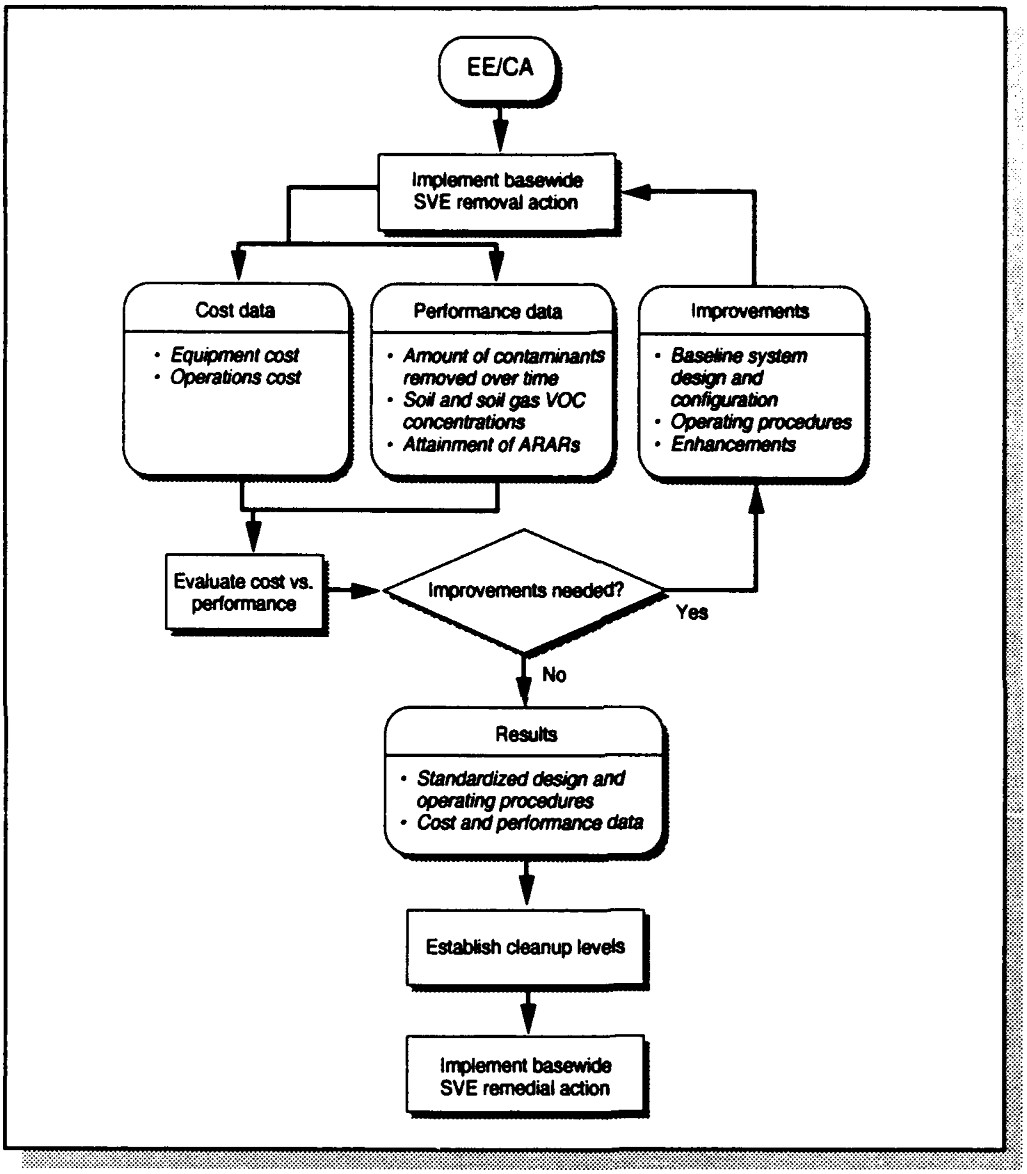

Figure 8-1
Basewide SVE Removal Action: Laying the Foundation for Basewide SVE Application

Section 8

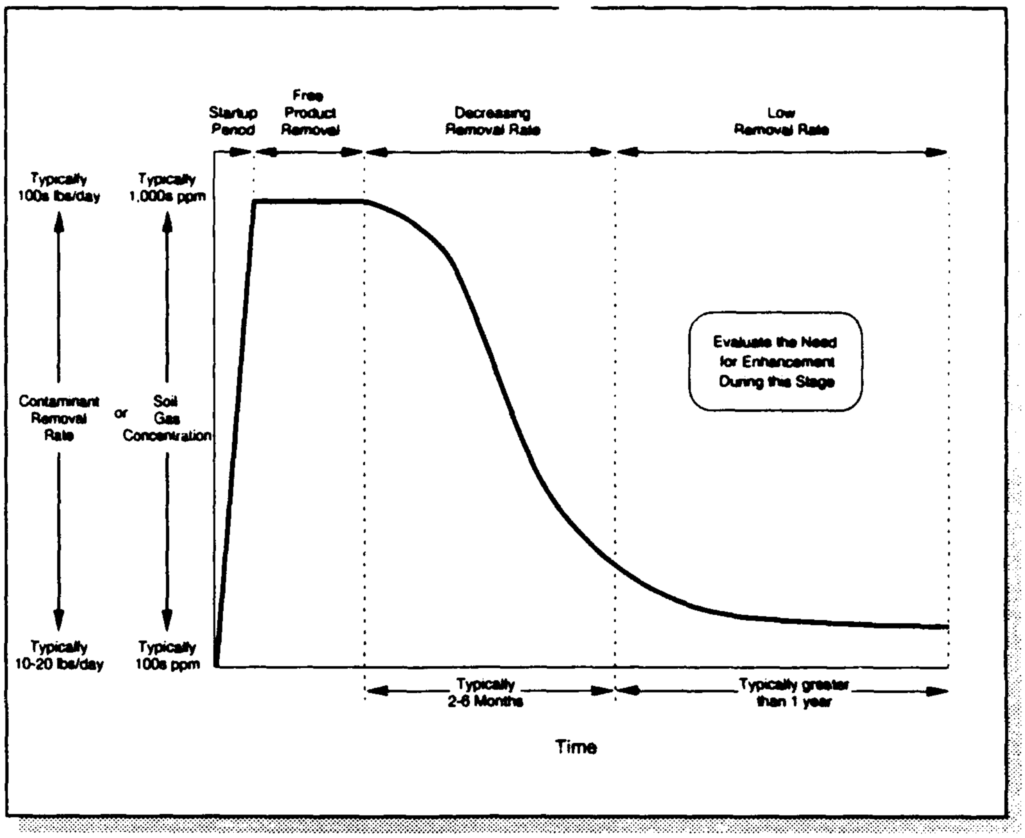

Figure 8-2
Typical Mass Removal Rate During Operation of SVE Systems (Not to Scale)

include: reconfiguring the system to focus on remaining zones of contamination, operating the system by "pulse pumping" to economize energy uses, and injecting hot air to enhance the desorption and diffusion of VOCs.

Since feasible soil cleanup levels have not yet been developed for McAFB, the SVE systems are likely to continue to operate until such decisions are made. As basewide SVE removal actions progress, cost and performance data will be generated, thus providing McAFB and the regulatory agencies with a better basis for establishing VOC cleanup levels for soils.

Once feasible soil VOC cleanup levels are established, SVE removal actions may transition into a final remedy for VOC contamination at the site. A site is considered to be fully remediated if soil VOC concentrations remain below cleanup levels after termination of SVE operations.

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GLOSSARY

Chemical Codes

ACE	acetone
BRME	bromomethane
BUTADIEN	1,3-butadiene, erythrene
BZ	benzene
BZLCL	benzyl chloride
BZME	toluene
C8N	n-octane
CHLOROPR	2-chloro-1,3-butadiene
CLBZ	chlorobenzene
CLEA	chloroethane
CLME	chloromethane
CO	carbon monoxide
CTCL	carbon tetrachloride
CYHEXANE	cyclohexane
DCA11	1,1-dichloroethane
DCA12	1,2-dichloroethane
DCBZ12	1,2-dichlorobenzene
DCBZ13	1,3-dichlorobenzene
DCBZ14	1,4-dichlorobenzene
DCE11	1,1-dichloroethene
DCE12C	cis-1,2-dichloroethene
DCE12T	trans-1,2-dichloroethene
DCP13C	cis-1,3-dichloropropene
DCP13T	trans-1,3-dichloropropene
DCPA12	1,2-dichloropropane
EBZ	ethylbenzene
EDB	1,2-dibromoethane (ethylene dibromide)
FC11	trichlorofluoromethane
FC113 or F113	1,1,2-trichloro-1,2,2-trifluoroethane
FC114	freon 114, dichlorotetrafluoroethane
FC12	dichlorodifluoromethane
HCl	hydrochloric acid
MTLNCL	methylene chloride
MVC	vinyl chloride, monovinylchloride
NOx	nitrogen oxides
PCA	1,1,2,2-tetrachloroethane
PCE	tetrachloroethene
PROP	propylene, propene
SOx	Sulfur Oxides
STY	styrene
TBME	bromoform

GLOSSARY

TCA111	1,1,1-trichloroethane
TCA112	1,1,2-trichloroethane
TCB124	1,2,4-trichlorobenzene
TCE	trichloroethene
TCLME	chloroform
TMB124	1,2,4-trimethylbenzene
TMB135	1,3,5-trimethylbenzene (mesitylene)
UNK	unknown compounds
VC	vinyl chloride
XYLMP	m,p-xylene (sum of isomers)
XYLO	o-xylene (1,2-dimethylbenzene)
XYLP	p-xylene (1,4-dimethylbenzene)

General

ARAR	Applicable or relevant and appropriate requirement
cfm	Cubic feet per minute
EE/CA	Engineering Evaluation-Cost Analysis
EPA	U.S. Environmental Protection Agency
IAG	Interagency Agreement
IC	Investigative cluster
IRP	Installation Restoration Program
IWL	Industrial waste line
IWTP	Industrial wastewater treatment plant
MCAFB	McClellan Air Force Base
OU	Operable Unit
ppb	parts per billion
ppm	parts per million
ppmv	parts per million by volume
PRL	Potential release location
scfm	standard cubic feet per minute
SMAQMD	Sacramento Metropolitan Air Quality Management District
SVE	Soil vapor extraction
TOC	Total organic carbon
TRC	Technical Review Committee
VOC	Volatile organic compound